BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XXVI. ENTRAINMENT OF PHYTOPLANKTON AT THE DONALD C. COOK NUCLEAR PLANT - 1976

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The Donald C. Cook Nuclear Plant is a 2200 Megawatt steam electric generating station situated on the southeastern shore of Lake Michigan about 18 km south of St. Joseph, Michigan. At full operation, the plant will use roughly 6300 $m^{-3} min^{-1}$ of lake water in once-through cooling of its condensers. Waste heat is returned to the lake in cooling water heated to a maximum of 12-13C° above intake temperature for unit #1 and 9-10C° above lake temperature for unit #2 as stated in the Technical Specifications for the plant. The plant uses chlorination twice daily for chemical defouling of heat exchangers and turbine condensers. At the time of sampling, only unit #1 of the plant was operating. It uses roughly 2700 $m^{-3} min^{-1}$ of lake water for once-through cooling.

The Environmental Technical Specifications of the plant require an assessment of phytoplankton abundance, viability, and species composition to be made on a monthly basis on samples collected in the early morning, at mid-day, and in late evening.

INTRODUCTION

Past studies have shown that phytoplankton may suffer inhibition or even death due to entrainment and condenser passage. In addition, changes in community structure have been noted. Various authors have concluded that temperature rises which can be tolerated range from 8C° to 11C°. The actual delta-T permissible is related to the intake water temperature. The lower the intake water temperature the greater the tolerable temperature rise. If chlorination is also taking place, the phytoplankton may be killed outright or suffer varying degrees of inhibition.

At elevated temperatures, communities have been observed to exhibit decreased diversity promoted by a shift from a diatom dominated community to one dominated by either green algae or blue-green algae in heated waters.

Finally, some evidence exists which suggests that the phytoplankton may be mildly stimulated by mechanical pumping (Gurtz and Weiss 1972).

Previous Studies at the Cook Plant

In response to the above possible alterations of the phytoplankton community in the vicinity of the Plant, two major studies have been initiated. The first began in 1968. It is directed at determining the long-term effect of the plant on the phytoplankton. This study includes the counting and identification of phytoplankton species at both plant-influenced and non-influenced stations. These data have been used to establish pre-operational phytoplankton trends and variations in the lake against which operational data can be compared. The results of these studies have been reported by Ayers *et al.* (1970), Ayers *et al.* (1971), Ayers *et al.* (1972), Ayers and Seibel (1973), Ayers *et al.* (1974), Ayers and Kopczynska (1974), Ayers (1975a), Ayers (1975b), Ayers *et al.* (1977), and Ayers (1978).

The second study is being used to ascertain the immediate effect of the plant on the entrained phytoplankton. It will also be used to monitor long-term changes in the phytoplankton. Results of this continuing study for the year 1976 are presented here. The monitoring results for 1975 are found in Rossmann *et al.* (1977).

SAMPLE HANDLING AND ANALYSIS

Studies pertaining to entrained phytoplankton at the Donald C. Cook Nuclear Power Plant unit #1 began in February 1975 and continue at present. Investigation of plant impact on phytoplankton viability, abundance, and species composition has been made in accordance with the Environmental Technical Specifications for the plant. Sampling was conducted on a monthly basis with three approximately one-half hour sampling periods in a 24 hour span: after evening twilight, before morning twilight, and at noon, respectively. During each sampling period, ten samples were collected, five from the intake forebay and five from the discharge forebay (Figure 1). Of each five, two samples were preserved for microscopic investigation of abundance and species composition, and the remaining three were used for spectrophotometric determination of chlorophylls *a*, *b*, and *c* and phaeophytin *a* with subsequent calculation for the phaeophytin *a*/chlorophyll *a* ratio as an indicator of phytoplankton viability. During the first sampling period, three additional samples were collected from both the intake and discharge forebays. These six samples were incubated at the intake temperature for approximately 36 hours and then treated in the same manner as non-incubated samples for analysis of the chlorophylls and phaeophytin *a*.

Throughout 1976, samples were collected at intake grate MTR 1-5 from a depth of 5.5 m. A study horizontal and vertical phytoplankton concentrations in the intake forebay has confirmed our choice of MTR 1-5 at a depth of 5.5 m as a representative sampling point (Rossmann *et al.* 1977).

Water was collected through hoses at a rate of roughly 227 l/min by diaphragm pumps. As the water was pumped, the intake and discharge water

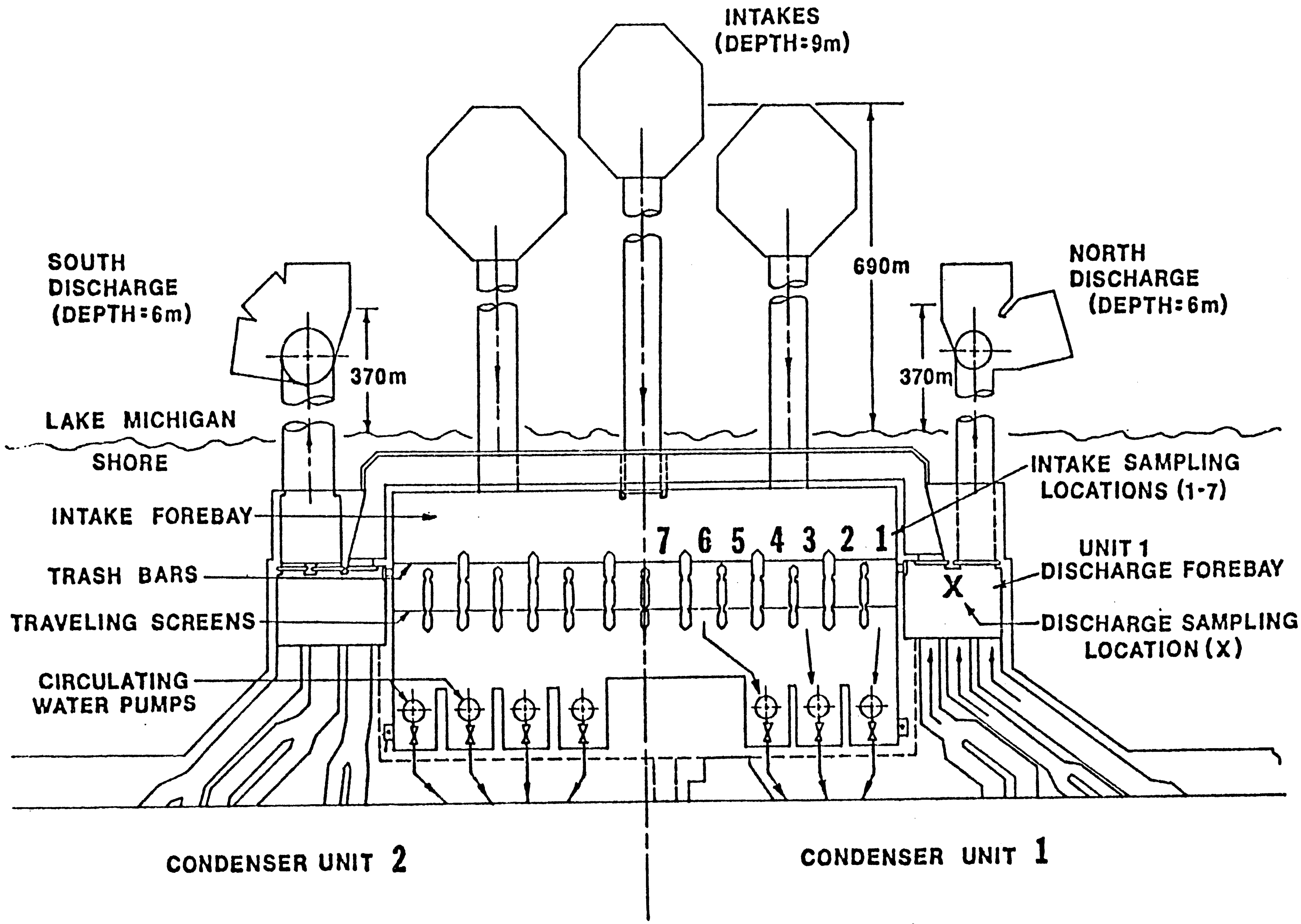

FIG. 1. Sampling locations in the Donald C. Cook Nuclear Plant screenhouse.

temperatures were measured and samples were collected in one liter polyethylene bottles. Since unit #1 uses 2.7×10^6 l min^{-1} for cooling, the samples collected during a one-half hour sampling time represent approximately 4×10^{-6}% of the water passing through the plant for the chlorophylls and 2×10^{-6}% of the water passing through the plant for the microscopic phytoplankton analysis.

Phytoplankton

Phytoplankton samples were collected from both the intake and discharge forebays (Figure 1). They were, for the most part, collected in duplicate in twice rinsed one liter brown polyethylene bottles and fixed with 6 ml of Lugols' iodine-potassium iodide-glacial acetic acid solution. Slide preparation was similar to the settle-freeze method of Sanford *et al.* (1969). One liter samples were settled in graduated cylinders for two days, after which time 900 ml of supernatant was siphoned off. The remaining 100 ml was then agitated to resuspend the settled matter and 18 ml poured into a cylindrical plexiglass settling chamber with a microscope slide at its base. Various dilutions were used to facilitate enumeration and identification when there were high concentrations of suspended material. The chambers were secured to the slides with a minimal amount of stopcock grease on their ends, and the cylinder-slide combinations were held by clamps onto a quarter inch thick aliminum plate. Freezing of the bottom 1.5 ml was accomplished by placing the entire apparatus on a block of dry ice for approximately 85 seconds. The supernatant was poured off and when the ice at the bottom of the chamber had melted sufficiently, the chamber was removed from the slide and the slide with its thin wafer of ice and water was dehydrated in an anhydrous alcohol chamber

for two days. This was followed by two days in a toluene chamber to prepare the sample for permanent mounting under a cover slip in Permount.

All counting was done on a Leitz Ortholux microscope at 1250X with a stage micrometer calibrated field width of 90 μm. Identification of specimens was carried to species and variety when possible. Enumeration was all in cells per milliliter except for blue-green filaments with cylindrical trichomes which were in filaments per milliliter. Two complete transects were made on each slide, one horizontal and one vertical, to help offset any patchiness that could occur in distribution. A minimum of 500 cells was counted for each slide to insure reasonable group percentages, more transects and/or higher counts being necessary if a fairly large number of proportion of the cells were in colonial formations.

Chlorophylls and Phaeophytin *a*

The samples selected for incubation were immediately placed in an incubator with the bottle caps removed and allowed to incubate for 36 hours at the intake temperature. Following this they were filtered and treated in the same manner as the non-incubated samples, a modification of the method described by Strickland and Parsons (1972). Each water sample was passed through a 4.25 cm diameter Whatman GF/C glass fiber filter positioned in a 250 ml Millipore filtering apparatus with plastic-tipped forceps. After most of the water had passed into the filtering flask, 1 ml of saturated $MgCO_3$ was added (1 g $MgCO_3 \cdot 4H_2O$/100 g distilled water). The filters were rolled up with the forceps and placed in 12 ml screw cap centrifuge tubes whose caps were teflon lined. Following this, 10 ml of 90% acetone was added using a tilting repipet and the samples were refrigerated. The 90% acetone was prepared by swirling

reagent grade acetone with anhydrous Na_2CO_3 and passing it through a Whatman #4 filter containing some additional Na_2CO_3. The acetone was filtered a second time into a volumetric flask containing the appropriate amount of distilled water for a 90% solution (v/v). 500 to 1000 ml portions were made fresh for each month's sampling.

After sampling was completed the extracts were packed on ice in a styrofoam chest and returned to the laboratory. Upon arrival they were inverted three times and then sonified by placing the tubes, six at a time, in a large beaker of crushed ice and water and sonifying at 70% power (Bransolik III sonifier) for 45 seconds. The samples were then allowed to further extract for at least another 15 hours under refrigeration. The tubes with the extracts were again shaken to break up the filters somewhat and then placed in ice water in 22 x 130 mm conical centrifuge tubes. The samples were centrifuged for two minutes at 2100 rpm, to separate the extract from filter fibers and $MgCO_3$. The extract was then decanted into clean tubes using disposable pipets and recentrifuged under the same conditions. This second centrifugation was performed to minimize the problem of filter fibers interfering with the spectrophotometer measurements. Samples were then returned to the refrigerator and taken out individually to warm to room temperature in a small, light-tight centrifuge prior to analysis.

A Beckman model DU spectrophotometer was used for all chlorophyll analyses. Wavelength calibration was made using holmium oxide glass at 453.4 nm. A set of four 10 cm silica cuvettes (5 ml volume) was used for the analyses. Percent transmittance of the extracts relative to 90% acetone was measured at 665, 645,

630, and 750 nm. Four drops (0.1 ml) of 30% HCl were added to the sample in the cuvette with thorough mixing, and percent transmittance was again measured at 665 and 750 nm after four minutes. Data were converted to absorbances and quantities of the various species were calculated using the Strickland and Parsons (1972) equations for chlorophylls *b* and *c* and the Lorenzen equations (Strickland and Parsons 1972) for chlorophyll *a* and phaeophytin *a*. Results were expressed as milligrams per cubic meter for each species.

Nutrients

All samples for orthophosphate, dissolved silica, nitrate, and nitrite analysis were filtered through 0.45 μm pore size membrane filters immediately after collection. Orthophosphate was complexed as phosphomolybdate and extracted into isobutanol using the methodology described by Sutherland *et al.* (1966). Dissolved silica was reacted with ammonium molybdate in an acid medium following the methodology of Sutherland *et al.* (1966). Analysis for nitrate and nitrite followed the methodology of Strickland and Parsons (1972). By this method, samples for nitrite analysis were measured after reaction with sulfanilamide and N(1- napthyl) ethylene diamine dihydrochloride. Samples for nitrate analysis were first passed through a cadmium column to reduce the nitrate to nitrite. These were then treated in the same manner as the nitrite samples.

CONDITIONS AT TIME OF COLLECTION

Temperature

Water temperatures at time of sample collection are presented in Table 1.

TABLE 1. Entrainment temperatures for 1976.

Date	Time	Intake, °C	Time	Discharge, °C
January 13, 1976	~1915	2.1	~1930	13.0
14	0608-0616	1.8	0622-0628	13.0
14	1220-1232	2.8	1235-1242	13.7
February 10, 1976	2000-2011	2.0	2014-2023	14.1
11	0600-0610	1.9	0615-0620	14.3
11	1220-1235	1.8	1222-1230	2.2
March 9, 1976	2030-2045	4.3	2048-2100	13.1
10	0505-0515	3.8	0518-0523	15.0
10	1218-1223	3.5	1225-1228	15.0
April 5, 1976	2101-2109	8.2	2113-2120	18.5
6	0600-0605	7.1	0605-0630	17.1
6	1215-1220	7.0	1206	17.5
May 10, 1976	2120-2133	12.1	2130	17.9
11	0345	12.0	0330	19.9
11	1115	12.8	1105	21.3
June 14, 1976	2315	20.4	2240	31.1
15	0340-0345	20.0	0330-0335	31.0
15	1120-1130	20.0	1131-1136	30.9
July 12, 1976	2250-2255	16.0	2255	24.0
13	0340	14.5	0348	26.2
13	1220-1230	15.1	1230	23.2
August 9, 1976	2150	21.0	2135	32.5
10	0405-0415	20.5	0350-0400	32.0
10	1230-1235	21.0	1210-1220	32.1
September 22, 1976	2130-2138	19.0	2142-2150	29.1
23	0555-0604	18.3	0607	28.8
23	1155-1210	18.9	1143-1149	29.2
October 11, 1976	1930-1945	16.0	1940-1945	26.2
12	0524-0529	15.1	0530-0535	26.0
12	1226-1232	15.3	1217-1222	26.0
November 8, 1976	1845-1850	7.4	1855-1900	18.0
9	0800-0805	6.9	0807-0812	16.8
9	1317-1325	6.7	1310-1315	16.9
December 15, 1976	1920-1925	5.8	1912-1917	15.0
16	0735-0740	3.0	0725-0730	13.0
16	1320-1330	3.0	1310	13.1

In addition, this table contains dates and times of collection. In 1976, Lake Michigan in the vicinity of the D. C. Cook Plant began to stratify in May. The lake returned to isothermal conditions during the fall overturn in late October. Deicing of the plant's intakes by recirculating heated water out through the center intake pipe began in January and ended in March.

Physical

Throughout 1976 several other physical events occurred which can affect phytoplankton abundances and community composition. These were upwellings and storms, occurring during the period of thermal stratification. Known storms at the time of our sampling occurred on May 11, June 16, October 12, and November 9 through 12. Upwellings were observed June 19 through 22, June 30 through July 1, July 12 through 14, July 31 through August 3, September 2 through 3, and September 9 through 10. Each upwelling transported a new water mass with its intrained phytoplankton and higher nutrient concentrations to the nearshore region. Each storm mixed the epilimnion and may have entrained some of the hypolimnion. This gives rise to a new mixed phytoplankton population and higher nutrient concentrations.

Chlorination

Chlorination occurs twice daily at the Cook Plant. In each case, the period of chlorination is one-half hour. Table 2 is a compilation of the chlorination times for those days the plant was operating in 1976. At no time did our normal sampling coincide with the chlorination times.

Nutrients

The monthly variation of nutrient concentrations reflects spring runoff, storm activity, upwellings, and nutrient uptake by phytoplankton. During 1976,

TABLE 2. Chlorination times on the days of phytoplankton entrainment.

Date	Time, EST
January 13	--
14	--
February 10	--
11	--
March 9	1000, 2200
10	1000
April 5	1000,2200
6	1000,2200
May 10	--
11	--
June 14	0700, 1900
15	0700, 1900
July 12	--
13	--
August 9	0700, 1900
10	0700, 1900
September 22	1900
23	0700
October 11	1000, 2200
12	1000, 2200
November 8	1000, 2200
9	1000, 2200
December 15	--
16	--

the nutrients measured the entire year were orthophosphate and dissolved silica. Nitrate was measured during September through December. Table 3 contains results of these measurements. Both orthophosphate and dissolved silica were high during January through March reflecting spring runoff. In April, decreases in both occured during increased phytoplankton uptake, primarily by diatoms. During May, storm activity gave rise to an increase in orthophosphate. In July, August, and September upwellings continued to contribute to increased orthophosphate and dissolved silica concentrations. In October through December, storms and a return to isothermal conditions provided some nutrients. It appears that nutrient regeneration in the hypolimnion occured only during periods of most intense thermal stratification. Nutrient concentrations increased in the hypolimnion during quiescent periods and were released to the epilimnion as pulses during upwellings or strong storm occurrences. Thus in September, a strong pulse of both nutrients to the system was noted.

Nitrate utilized by algae decreased during September and October. With cessation of thermal stratification, nitrate concentration increased in December. Thus, as phytoplankton data are interpreted, the monthly availability of nutrients must be also considered.

RESULTS AND DISCUSSION

Phytoplankton

Each of the conditions discussed in the previous section can have an impact upon the abundances and community structure of the phytoplankton. When they are believed to be important to the interpretation of observed variations

TABLE 3. Monthly variation of nutrients during 1976.

Month	Orthophosphate ppb P		Dissolved Silica ppm SiO_2		Nitrate ppm NO_3	
	M[1]	SE[2]	M[1]	SE[2]	M[1]	SE[2]
January	2.88	0.200	1.23	0.0361		
February	1.62	0.0869	0.949	0.0926		
March	1.22	0.0578	1.21	0.0200		
April	0.701	0.0478	0.849	0.0		
May	2.06	0.0742	0.246	0.00400		
June	0.809	0.0424	0.0495	0.0140		
July	1.89	0.234	0.918	0.0176		
August	2.36	0.722	0.745	0.0312	0.994	0.0492
September	1.53	0.368	1.03	0.0577	0.628	0.0174
October	0.908	0.0	0.845	0.0377	0.717	0.0144
November	1.41	0.179	0.615	0.108	0.855	0.0307
December	0.869	0.0610	0.428	0.0153	1.07	0.0645

[1] mean

[2] standard error

in the phytoplankton community, further discussion will be necessary. The complete compiled results of the 1976 entrainment phytoplankton microscopic counts are contained in Appendices 1 and 2. For the ease of the reader, these data have been tabulated in several ways to provide: 1) an overview of monthly variations of major groups of phytoplankton, of taxonomic dominance, and of community structure and 2) a comparison of these results with those of 1975.

Monthly Variations of Entrained Major Phytoplankton Groups

The number of phytoplankton in a particular major group goes through a predictable succession throughout a calendar year. The major groups considered are coccoid blue-green algae, filamentous blue-green algae, flagellates, centric diatoms, pennate diatoms, desmids, other algae, and total algae. The succession of diatoms, blue-green algae, green algae, and flagellates is of importance. Diatom concentrations are relatively high from January through their peak spring concentrations in April or May. After thermal stratification, usually in May, dissolved silica becomes depleted, water temperature rises, and diatom numbers decrease. These low concentrations continue until October or November when decreasing water temperature and mixing processes return the lake to an isothermal condition. Concomittant with the decrease in temperature is an increase in dissolved silica, other nutrients, and diatom concentrations. Diatoms reach peak winter concentrations during December through January.

Green algae concentrations are low during January through May or June.

They reach peak concentrations during the warm water months of May through September. Concentrations decline during October through December.

Blue-green algae are low in abundance during January through April or July. Numbers are highest during June through October when water temperatures are relatively high. Numbers decrease in November and December with decreased water temperature.

Flagellates are relatively low in concentration during January through March or April. Highest concentrations are reached in April or May with relatively high concentrations continuing through December.

These idealized successions are seldom found to completely match those found in a nearshore region of Lake Michigan where lake warm-up can vary in time or degree from year to year, large storms mix the nearshore zone, and upwellings occur. In addition, thermal effluents from power generation plants may alter or offset the "normal" succession.

Coccoid blue-green algae had high concentrations in January and decreased through July (Figure 2). Numbers were consistently high in August through December. This was different from what was observed in 1975. In 1975, the months May, July, September, and October had the highest counts and the concentrations varied greatly from month to month (Rossmann *et al.* 1977). In general concentrations were lower in 1976 than 1975.

With the exception of May, filamentous blue-green algae had consistently low concentrations in 1976 (Figure 3). This was somewhat similar to the 1975 results. In 1975, this peak concentration was reached in June rather than May (Rossmann *et al.* 1977). Concentrations in 1976 were similar to those of 1975.

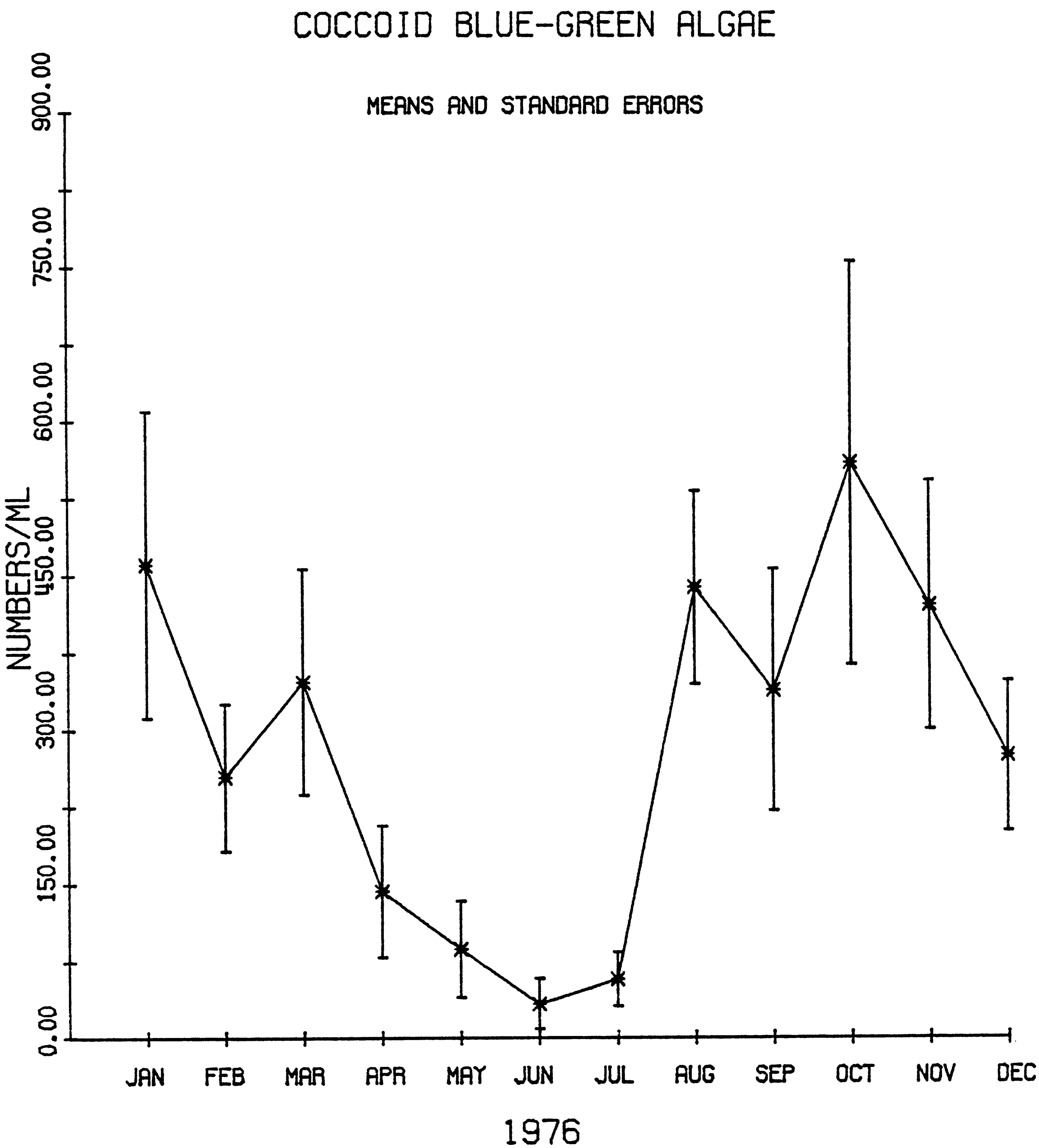

FIG. 2. Variation of coccoid blue-green algae numbers during 1976.

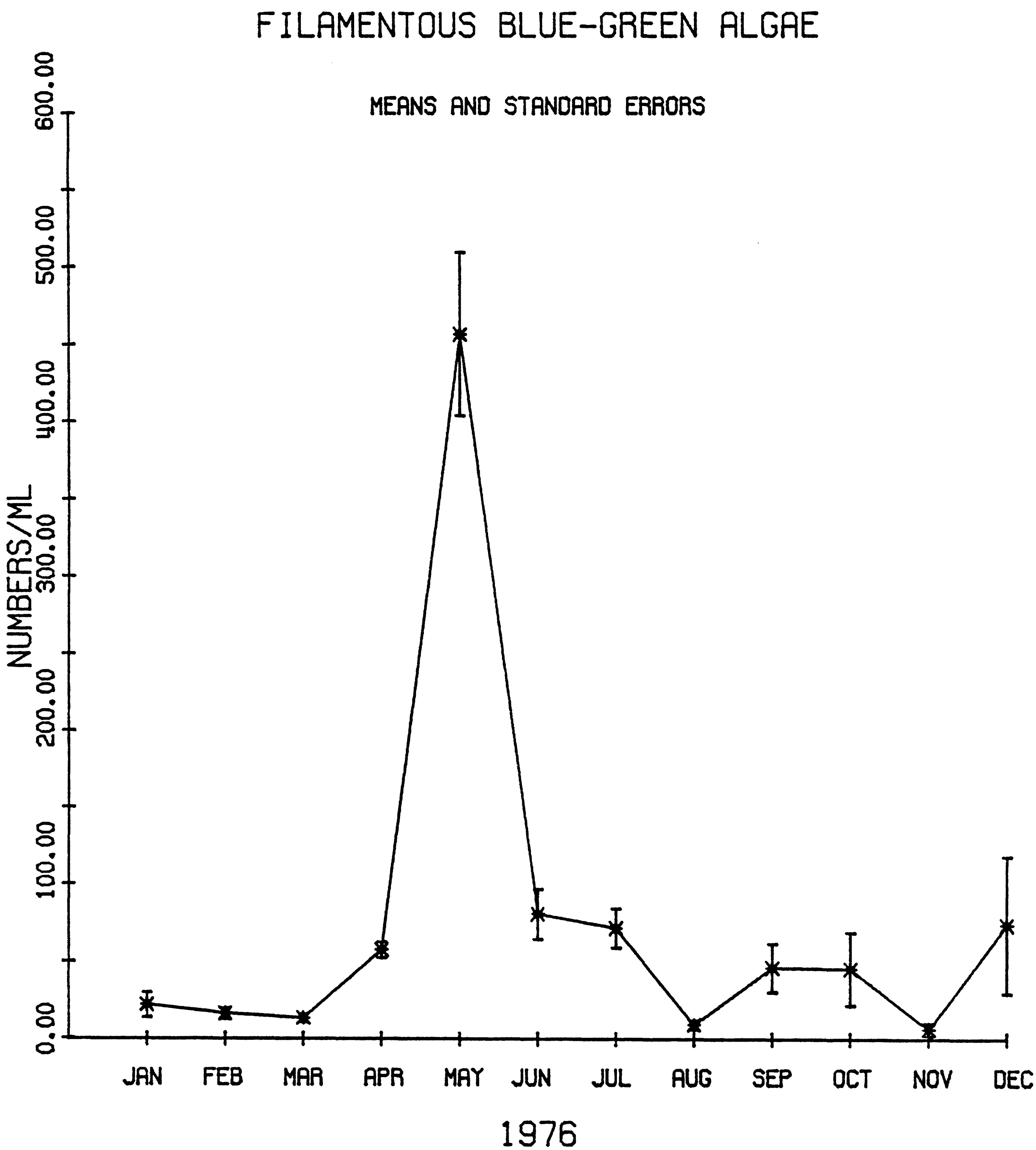

FIG. 3. Variation of filamentous blue-green algae numbers during 1976.

The 1976 coccoid green algae concentrations were low throughout the months of January through June (Figure 4). Peak numbers occured in July through September with slightly elevated concentrations in October through December. The 1975 results were similar with the exception that peak numbers occurred only in July with slightly elevated concentrations in August through December (Rossmann *et. al.* 1977). Concentrations were similar for the two years.

Filamentous green algae had relatively high concentrations in January and in May through July in 1976 (Figure 5). In 1975, relatively high concentrations occurred in March and June (Rossmann *et al.* 1977). Concentrations were about the same for 1975 and 1976.

During 1976, flagellates reached a peak concentration in May (Figure 6). Concentrations were consistently near 500-600 cells/ml in June through December. In 1975, no distinct peak concentration was observed; instead concentrations were 800 cells/ml in April and consistently decreased to 400 cells/ml in December (Rossmann *et al.* 1977). With the exception the peak concentration in May of 1976, concentrations of flagellates were similar in 1975 and 1976.

In 1976, centric diatom concentrations peaked in July (Figure 7). This peak was coincident with an upwelling event. Minor peak concentrations appeared in January and perhaps May. In 1975, the peak concentration occurred in April with a minor peak in December (Rossmann *et al.* 1977). Concentrations during these two years were quite similar.

Like the centric diatoms and for the same reason, pennate diatoms reached maximum abundance in July (Figure 8). Minor peaks occurred in

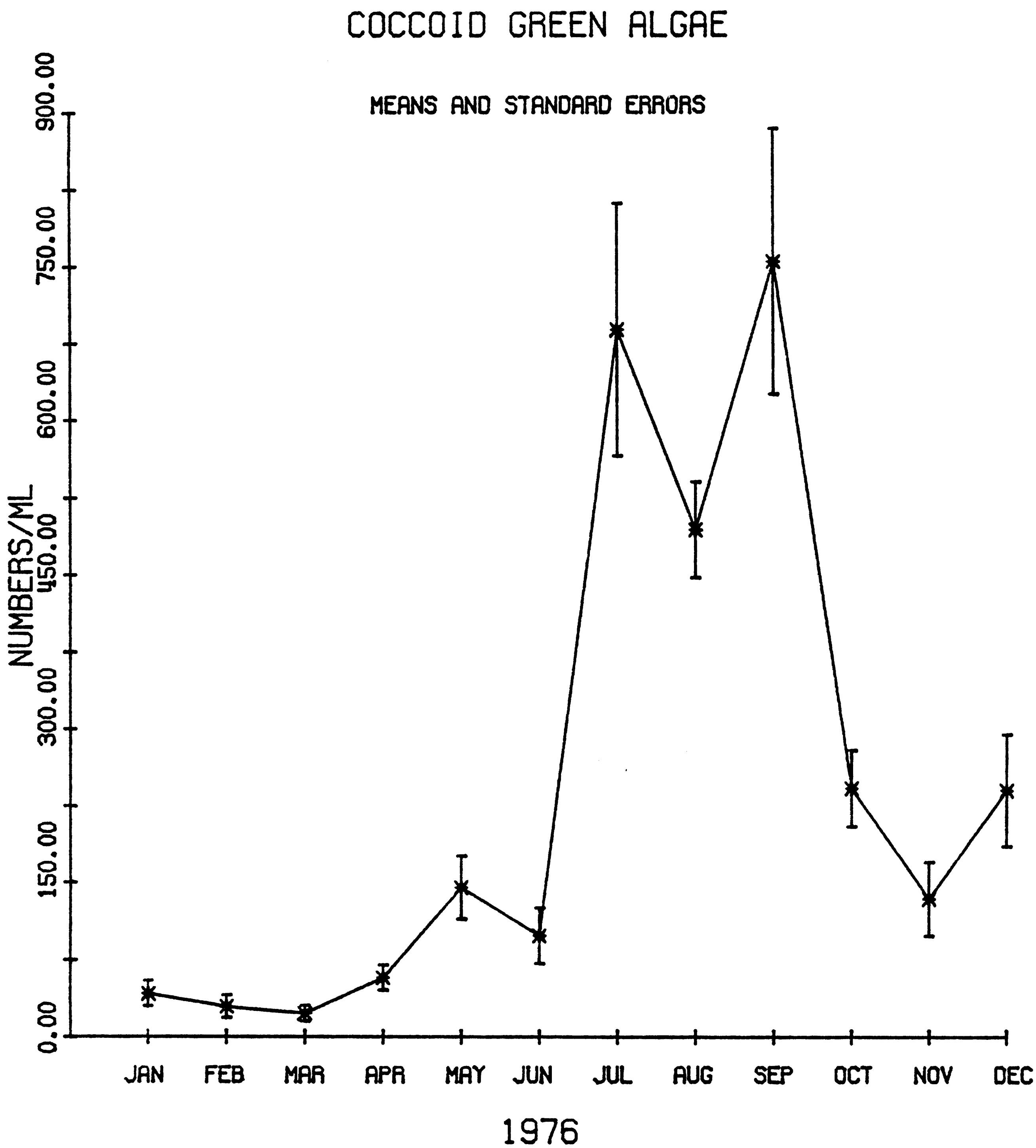

FIG. 4. Variation of coccoid green algae numbers during 1976.

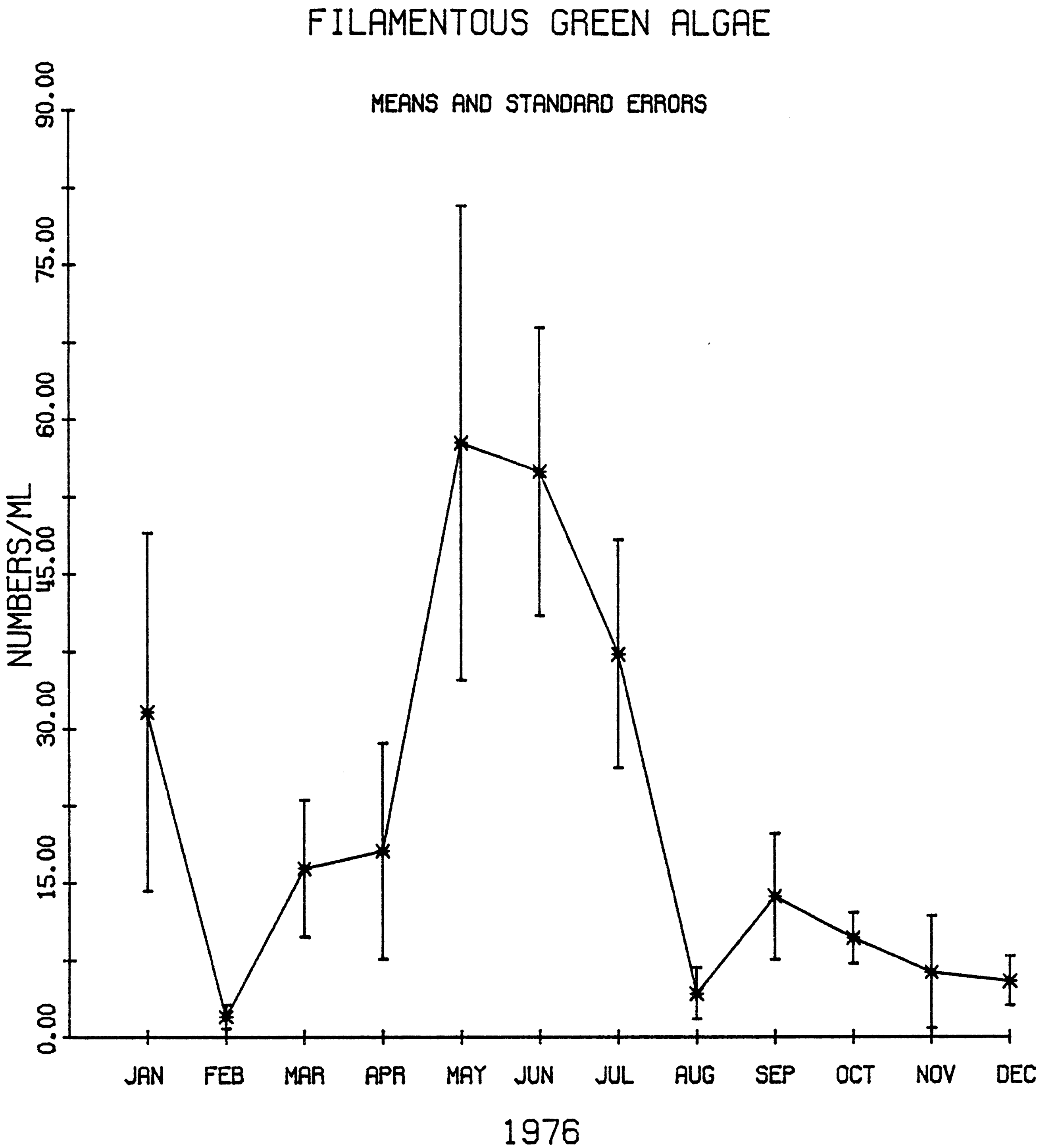

FIG. 5. Variation of filamentous green algae numbers during 1976.

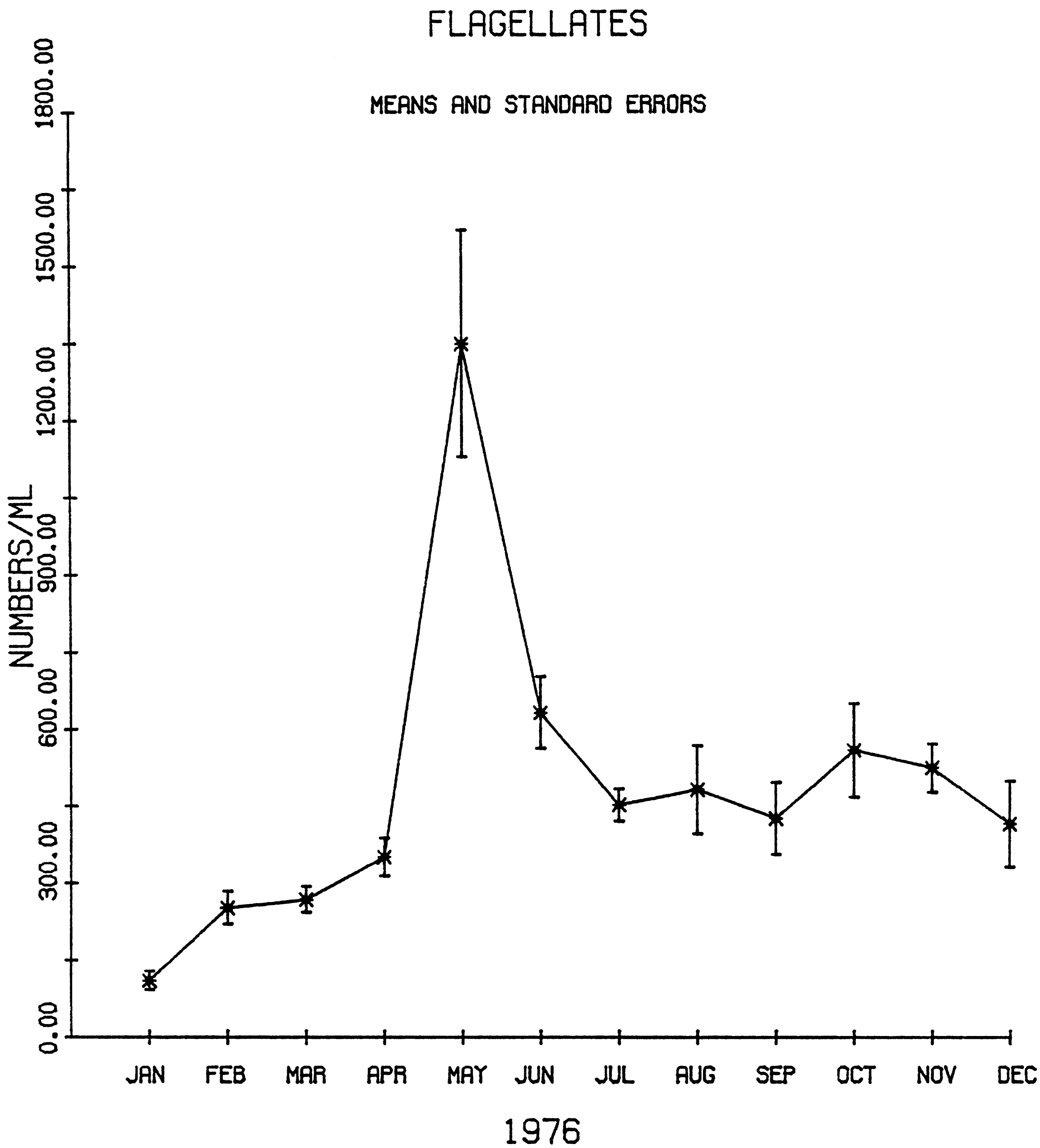

FIG. 6. Variation of flagellate numbers during 1976.

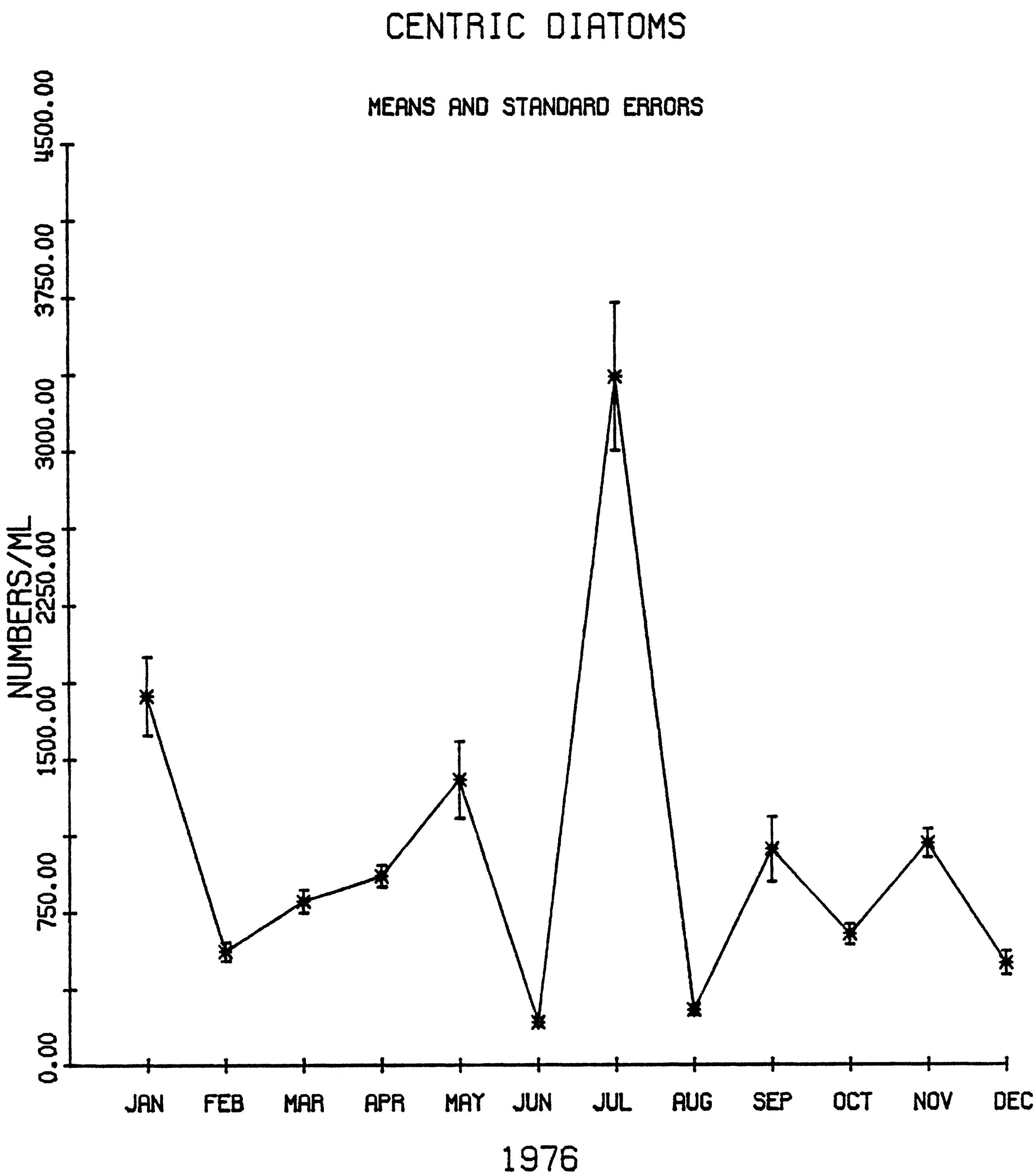

FIG. 7. Variation of centric diatom numbers during 1976.

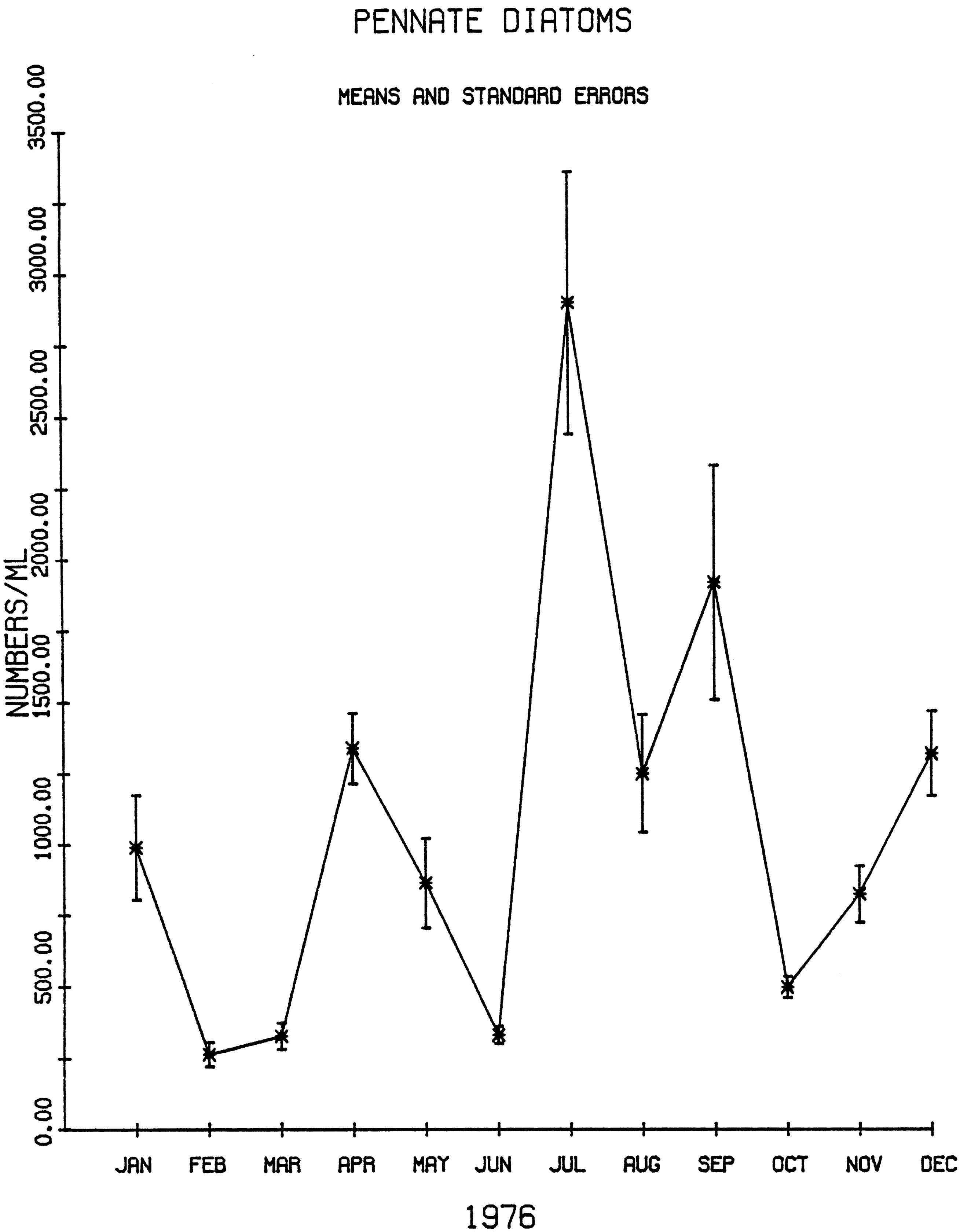

FIG. 8. Variation of pennate diatom numbers during 1976.

January, April, September, and December. In 1975, peak abundance occurred in May with a minor peak in February (Rossmann *et al.* 1977). In general, concentrations were higher in 1976 than 1975.

Desmids were consistently low throughout 1976 (Figure 9). Peak concentration was reached in May. In 1975, peak concentration was also reached in May (Rossmann *et al.* 1977). Concentrations were similar in 1976 and 1975.

All other algae reached peaked abundances in September with a secondary peak in July (Figure 10). This was very similar to the 1975 monthly abundances, with the exception that in 1975 there was no distinct peak abundance (Rossmann *et al.* 1977). Concentrations in 1976 were somewhat higher than those of 1975.

Total numbers of all algae reach a peak concentration in July coincident with an upwelling event (Figure 11). Secondary concentration peaks were evident for the months of January, May and September. In 1975, the peak concentration occurred in May with a secondary peak in July (Rossmann *et al.* 1977). In 1976, concentrations were similar to those of 1975.

The major differences between the years 1975 and 1976 were: 1) increased concentrations of pennate diatoms and other algae in 1976; 2) decreased concentrations of coccoid blue-green algae; 3) shifts in the months of peak concentrations which varied by no more than one month, between the two years; 4) the obvious impact of an upwelling in July 1976; and 5) the relatively high concentrations of coccoid blue-green algae during the early months of 1976. High coccoid blue-green concentrations during these months may be the result of deicing and/or recirculation of cooling water by the Donald C. Cook Nuclear Plant. Elevated winter concentrations of coccoid blue-green algae should be monitored closely in the future.

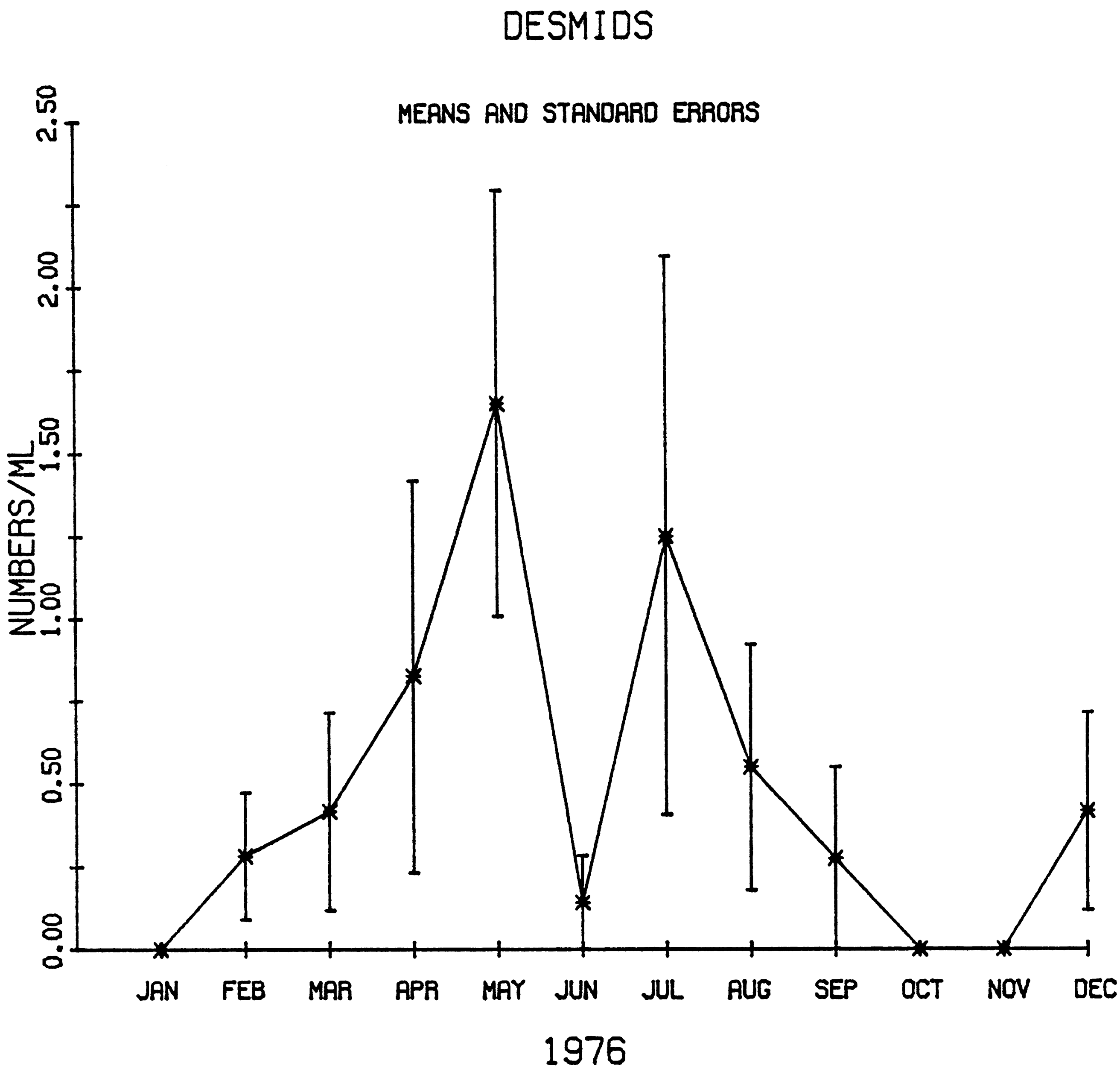

FIG. 9. Variation of desmid numbers during 1976.

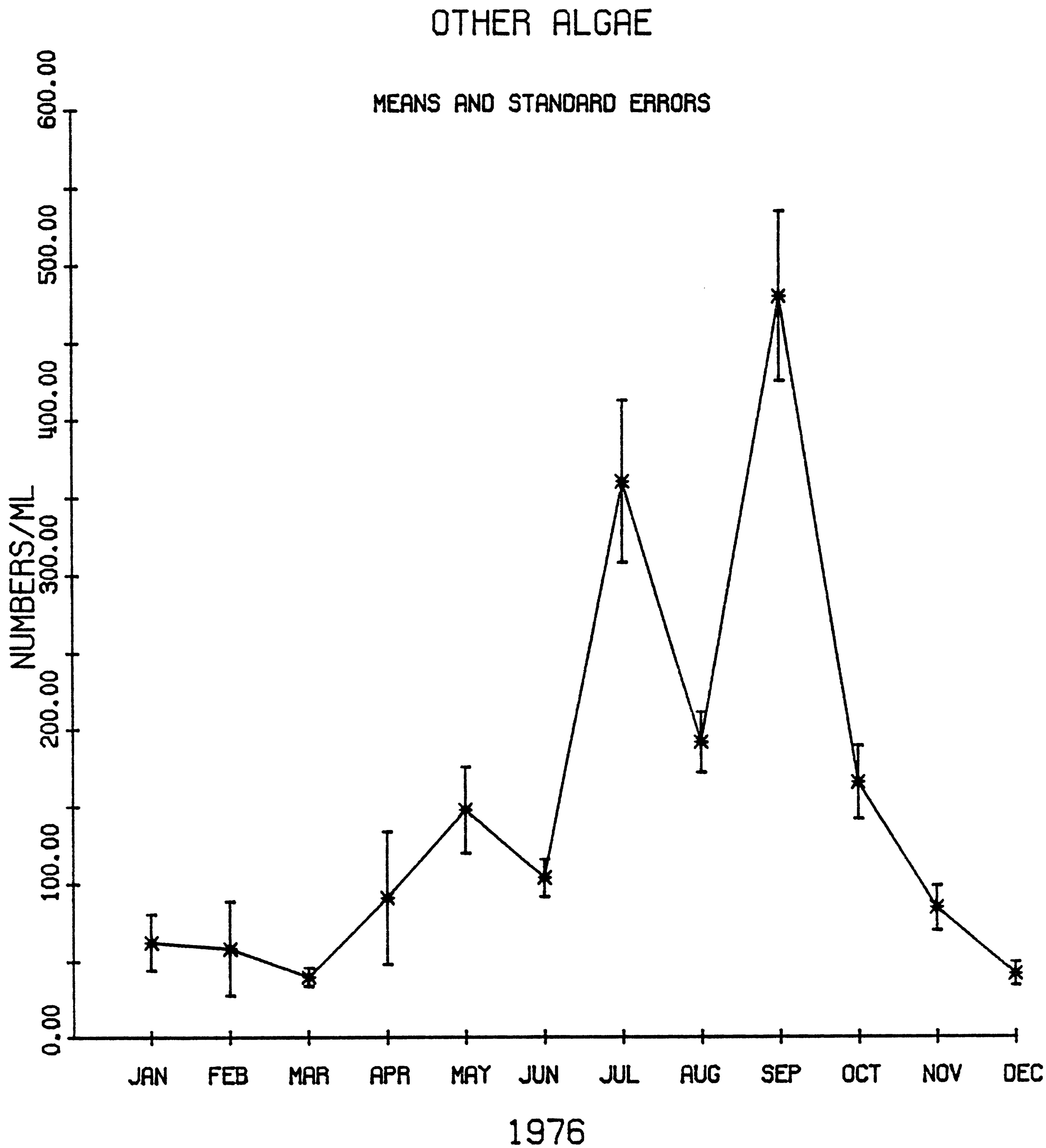

FIG. 10. Variation of other algae numbers during 1976.

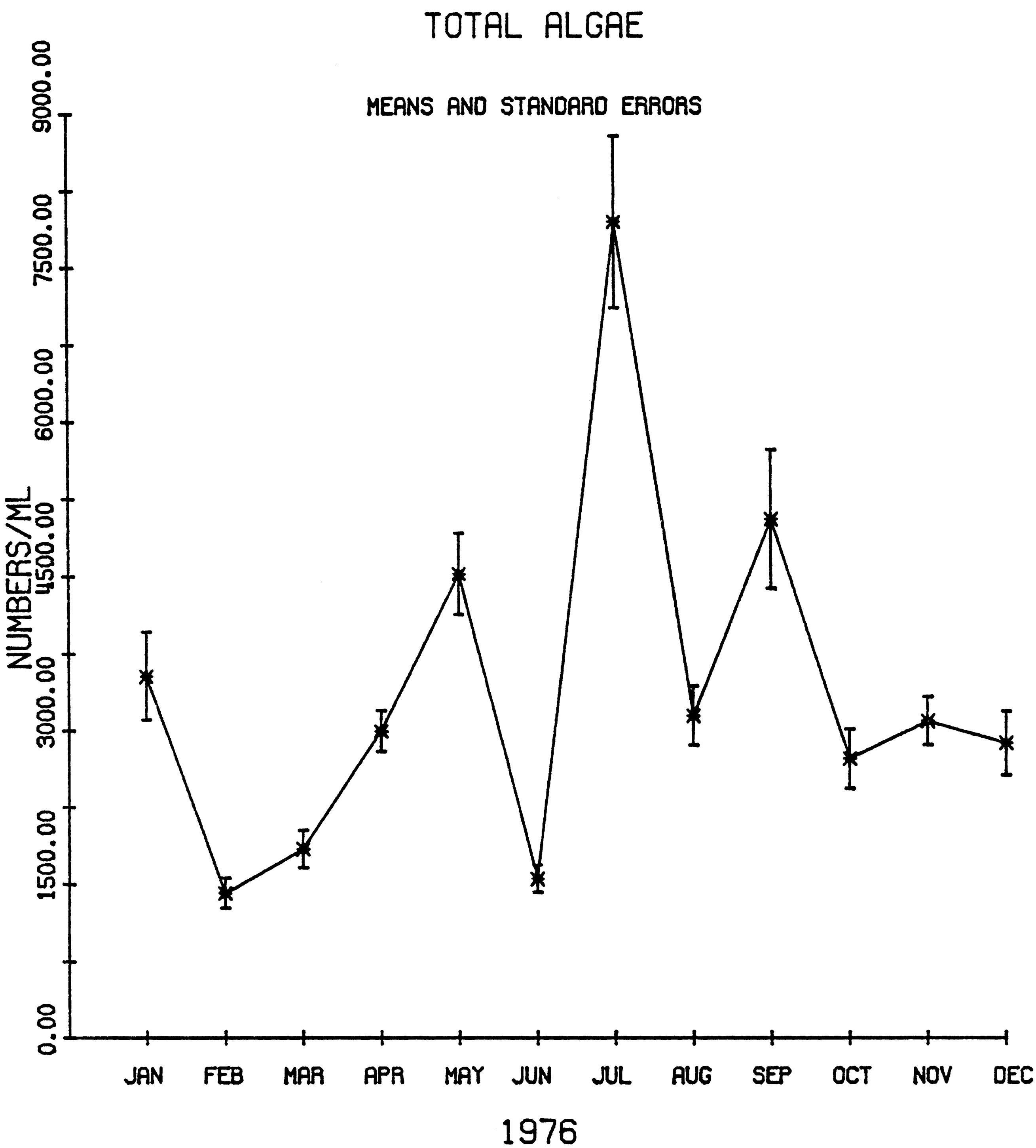

FIG. 11. Variation of total algae numbers during 1976.

Monthly Variations of Phytoplankton Community Structure

Community structure is discussed in terms of 1) relative proportion of total algae that each major group comprises, 2) occurrences of dominant and co-dominant forms, 3) number of forms occurring, 4) diversity, and 5) redundancy.

Relative Proportion of Total Algae that Each Major Group Comprises

During 1976, diatoms were dominant or co-dominant during each month (Table 4). They were dominant January through May and July through December. In June, they were co-dominant with the flagellates. This dominance by the diatoms was quite different from what was observed in 1975 (Table 4). In 1975, diatoms were dominant in February through June, co-dominant with blue-green and green algae in July, and dominant again in November and December. In August, flagellates were dominant. In September and October, blue-green algae were dominant. Thus in 1976, the Lake Michigan phtoplankton community in the vicinity of the Donald C. Cook Nuclear Plant was considerably different from that of 1975.

Occurrences of Dominant and Co-dominant Forms

Though large scale differences were not noted for the major groups, changes in community composition between 1975 and 1976 are evident. Tables 5 through 16 contain the number of times a dominant or co-dominant form occurred for each month of the years 1975 and 1976. During 1976, the number of dominant or co-dominant occurrences of Anacystis incerta, Anacystis thermalis, Stephanodiscus tenuis, Cyclotella stelligera, Cyclotella comensis, Tabellaria fenestrata v. intermedia, Dictyosphaerium pulchellum, Chromulina parvula, and Gomphosphaeria lacustris decreased. In 1976, the number of dominant or co-dominant occurrences of Stephanodiscus minutus, flagellates, Fragilaria

TABLE 4. Comparison of phytoplankton major group percentages for 1975 and 1976.

Month	Blue-Green Algae		Green Algae		Flagellates		Diatoms		Desmids		Others	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
January	--	13.7	--	2.1	--	3.1	--	79.3	--	0.0	--	1.8
February	4.6	19.2	1.9	2.2	17.9	3.1	90.2	58.6	0.0	0.0	0.2	2.1
March	9.5	19.5	2.7	2.1	8.2	14.5	78.8	61.6	0.0	0.0	0.9	2.2
April	6.8	6.7	1.0	2.5	17.0	11.7	73.8	75.9	0.0	0.0	1.4	3.0
May	13.6	12.0	0.8	4.5	11.0	30.0	73.0	50.1	0.0	0.0	1.5	3.3
June	14.8	7.3	4.6	10.0	21.6	40.9	54.9	35.1	0.1	0.0	3.9	6.7
July	27.4	1.4	23.8	9.3	13.4	5.7	23.9	79.0	0.1	0.0	11.4	4.5
August	23.2	14.2	15.6	15.8	39.7	15.3	17.1	48.5	0.0	0.0	4.4	6.1
September	52.3	7.6	7.4	15.2	24.7	8.4	14.3	59.1	0.0	0.0	1.3	9.5
October	42.0	22.3	4.8	9.2	28.0	20.5	23.4	41.9	0.0	0.0	1.8	6.1
November	28.9	13.9	6.5	4.6	19.4	17.0	42.1	61.9	0.0	0.0	3.1	2.7
December	6.8	12.2	4.5	8.6	13.2	14.5	72.9	63.3	0.0	0.0	2.5	1.4

TABLE 5. Occurrence of dominant forms in January 1975 and 1976.

Form	Occurrences 1975	Occurrences 1976
Centric Diatom, unknown	No Data	8
Cyclotella stelligera		4
Fragilaria crotonensis		3
Gomphosphaeria aponina		1
Stephanodiscus minutus		4
Gomphosphaeria lacustris		2
Anacystis incerta		1
Cyclotella sp.		1
Gomphosphaeria aponina v. delicatula		1

TABLE 6. Occurrence of dominant forms in February 1975 and 1976.

Form	Occurrences 1975	Occurrences 1976
Anacystis incerta	0	4
Stephanodiscus minutus	0	6
Coccochloris sp.	0	1
Flagellates	0	8
Centric diatom, unknown	0	2
Cyclotella sp.	0	1
Ochromonas sp.	0	1
Gomphosphaeria lacustris	1	2
Gomphosphaeria sp.	1	1
Cyclotella stelligera	4	0
Fragillaria crotonensis	4	0
Tabellaria fenestrata v. intermedia	7	0
Fragilaria capucina	1	0
Fragilaria intermedia	1	0
Stephanodiscus sp.	3	0

TABLE 7. Occurrence of dominant forms in March 1975 and 1976.

Form	Occurrences 1975	1976
Anacystis incerta	0	5
Cyclotella stelligera	4	6
Flagellates	1	9
Gomphosphaeria lacustris	2	3
Cyclotella sp.	0	3
Asterionella formosa	0	1
Blue green, unknown cells	0	1
Tabellaria fenestrata v. intermedia	9	0
Centric diatom, unknown	6	0
Stephanodiscus sp.	3	0
Fragillaria crotonensis	1	0

TABLE 8. Occurrence of dominant forms in April 1975 and 1976.

Form	Occurrences 1975	1976
Cyclotella stelligera	5	1
Flagellates	6	0
Fragilaria crotonensis	1	6
Gomphosphaeria lacustris	1	0
Stephanodiscus minutus	1	0
Stephanodiscus tenuis	2	0
Anacystis incerta	1	3
Asterioneila formosa	0	12
Flagellates	0	4
Rhizosolenia gracilis	0	3
Green colony, unknown	0	1
Fragilaria intermedia v. fallax.	0	1

TABLE 9. Occurrence of dominant forms in May 1975 and 1976.

Form	Occurrences 1975	1976
Anacystis incerta	4	0
Fragilaria crotonensis	4	0
Tabellaria fenestrata v. intermedia	5	0
Flagellates	4	11
Ochromonas sp.	0	5
Centric diatom, unknown	0	1
Oscillatoria limnetica	0	1
Rhizosolenia gracilis	0	1
Cyclotella sp.	0	1
Asterionella formosa	0	1
Stephanodiscus subtilis	0	1

TABLE 10. Occurrence of dominant forms in June 1975 and 1976.

Form	Occurrences 1975	1976
Flagellates	9	11
Tabellaria fenestrata v. intermedia	10	0
Fragilaria capucina	1	0
Stephanodiscus tenuis	2	0
Oscillatoria limnetica	2	0
Anacystis incerta	1	0
Gomphosphaeria lacustris	2	1
Fragilaria crotonensis	2	0
Chlorella sp.	0	1
Diatoma tenue v. elongatum	0	1
Dinobryon bavaricum	0	5
Dinobryon divergens	0	9

TABLE 11. Occurrence of dominant forms in July 1975 and 1976.

Form	Occurrences 1975	1976
Anacystis incerta	2	0
Cyclotella sp.	2	0
Cyclotella stelligera	9	0
Dictyosphaerium pulchellum	10	0
Gloeocystis sp.	9	1
Merismopedia tennuissima	1	0
Gomphosphaeria lacustris	1	0
Flagellates	4	0
Green coccoid, unknown	1	0
Gloeocystis planctonica	1	0
Stephanodiscus sp.	0	1
Centric diatom, unknown	0	5
Fragilaria crotonensis	0	5
Sphaerocystis sp.	0	1
Stephanodiscus subtilis	0	1

TABLE 12. Occurrence of dominant forms in August 1975 and 1976.

Form	Occurrences 1975	1976
Anacystis incerta	8	3
Chromulina parvula	9	0
Gomphosphaeria lacustris	3	2
Cyclotella stelligera	4	0
Gloeocystis sp.	5	4
Flagellates	3	5
Synura sp.	1	0
Fragilaria crotonensis	0	11
Gloeocystis planctonica	0	1
Chrysophycean flagellate sp.	0	1

TABLE 13. Occurrence of dominant forms in September 1975 and 1976.

	Occurrences	
Form	1975	1976
Anacystis incerta	11	4
Fragilaria crotonensis	2	8
Gomphosphaeria lacustris	5	0
Flagellates	6	1
Anacystis thermalis	4	0
Ochromonas sp.	2	0
Gloeocystis sp.	0	5
Sphaerocystis sp.	0	1
Chrysophycean flagellate sp.	0	1

TABLE 14. Occurrence of dominant forms in October 1975 and 1976.

	Occurrences	
Form	1975	1976
Anacystis incerta	10	5
Fragilaria crotonensis	1	2
Flagellates	8	9
Gomphosphaeria lacustris	6	2
Ochromonas sp.	3	0
Cyclotella comensis	0	2
Gloeocystis planctonica	0	1
Chrysophycean flagellate sp.	0	2
Gloecystis sp.	0	1

TABLE 15. Occurrence of dominant forms in November 1975 and 1976.

Form	Occurrences 1975	1976
Flagellates	7	8
Anacystis incerta	7	5
Chrysophycean flagellate sp.	2	0
Fragilaria crotonensis	6	4
Agmenellum quadruplicatum	1	0
Gomphosphaeria lacustris	4	0
Centric diatom, unknown	2	0
Stephanodiscus sp.	1	0
Sphaerocystis schroeteri	1	0
Cyclotella comensis	10	0
Cyclotella sp.	0	7
Tabellaria fenestrata v. intermedia	0	1
Asterionella formosa	0	2
Gloeocystis sp.	0	1

TABLE 16. Occurrence of dominant forms in December 1975 and 1976.

Form	Occurrences 1975	1976
Centric diatom, unknown	9	0
Cyclotella stelligera	9	0
Ochromonas sp.	3	0
Sphaerocystis schroeteri	1	0
Gomphosphaeria lacustris	1	1
Stephanodiscus minutus	1	0
Stephanodiscus sp.	1	0
Cyclotella comensis	1	1
Cyclotella sp.	1	0
Anacystis incerta	1	3
Fragilaria crotonensis	0	12
Flagellates	0	6
Fragilaria capucina v. lanceolata	0	1
Anabaena flos-aqaue	0	1
Gloeocystis planctonica	0	2

crotonensis, Asterionella formosa, Rhizosolenia gracilis, Dinobryon bavaricum, and Dinobryon divergens increased. On the whole in 1976, the dominant or co-dominant occurrences of blue-green algae decreased from 80 in 1975 to 48, green algae decreased from 26 in 1975 to 19, diatoms decreased slightly from 129 in 1975 to 104, Chrysophycean flagellates increased from 11 in 1975 to 24, and flagellates incresed from 48 in 1975 to 68. These numbers do not indicate any trend with regard to the trophic status of Lake Michigan in the vicinity of the Donald C. Cook Nuclear Plant.

Combining the list of diatoms indicative of tropic conditions compiled by Tarapchak and Stoermer (1976) with the results contained in Tables 5 through 16, a continuing eutrophication of Lake Michigan in this region is indicated. The diatoms species used are Stephanodiscus minutus, Cyclotella stelligera, Fragilaria crotonensis, Tabellaria fenestrata v. intermedia, Fragilaria capucina, Fragilaria intermedia, Asterionella formosa, Stephanodiscus tenuis, Stephanodiscus subtilis, and Diatoma tenue v. elongatum. The comparison yields an increase in dominant or co-dominant occurrences of eutrophic species from 6 in 1975 to 9 in 1976, an increase in occurrences of mesotrophic species tolerant of moderate nutrient enrichment from 55 in 1975 to 65 in 1976, and a decrease in occurrences of mesotrophic species not tolerant of nutrient enrichment from 31 in 1975 to 7 in 1976. Clearly this comparison shows that the lake has become more eutrophic in 1976 than 1975. This change is not limited strictly to the plant site but appears to be occurring in the entire region of this section of Lake Michigan (Ayers 1976).

Numbers of Forms, Diversity, and Redundancy

Diversity is calculated using the formula presented by Wilhm and Dorris (1968):

$$\bar{d} = -\sum_{i-1}^{S} (n_i/n) \log_2 (n_i/n)$$

where S is the number of species, n is the total number of phytoplankton in cell/ml, n_i is the number of phytoplankton of the i^{th} species. Diversity as presented here is not the true diversity since not all forms encountered can be identified to the species level. Therefore, this diversity must be viewed with caution. However, it will be used to illustrate changes ~~occuring~~ within the phytoplankton population form year to year. Number of forms is self-explanatory and will be used to indicate changes which may occur in the overall structure of the phytoplankton community. Redundancy is a measure of the dominance of one or a few species within a given population. As presented by Wilhm and Dorris (1968) it is:

$$r = \frac{\bar{d}_{max} - \bar{d}}{\bar{d}_{max} - \bar{d}_{min}}$$

where $\bar{d}$ is the observed diversity as calculated above, $\bar{d}_{max}$ is the maximum diversity for a particular community, and $\bar{d}_{min}$ is the minimum possible diversity for a particular community. $\bar{d}_{max}$ is calculated using the following equation:

$$\bar{d}_{max} = (1/n)(\log_2 n! - s \log_2 [n/S]!)$$

and $\bar{d}_{min}$ is calculated using the equation:

$$\bar{d}_{min} = (1/n)(\log_2 n! -s \log_2 [n-(S-1)]!)$$

The possible values of r range between 0 and 1. An r equal to 0 implies that all the species encountered in a community each have the same abundance of cells. An r equal to 1 implies that one species dominates the community of phytoplankton. Figures 12, 13, and 14 contain monthly means and associated standard errors for each month for number of forms, diversity and redundancy.

Throughout 1976 the number of forms was consistently around 60 with the exception of higher numbers in July and September (Table 17). These increases are attributed to upwelling events occurring before or during sampling. For each month of 1976, the number of forms was greater than that of the same month in 1975.

In 1976, diversity was high in July and September and low in August (Table 18). The high diversities in July and September most likely were a result of the upwelling events. The very low diversity in August was similar to that observed in August and September of 1975. For 1975 and 1976, the diversities started somewhere aroūnd 4.5 and decreased throughout the year to roughly 3.9 with the exception the anomolous highs and lows already discussed. Except for the high diversities associated with upwelling, the diversities for 1975 and 1976 were nearly the same.

Redundancy was quite consistent in 1976 with the exception of August, November, and December (Table 19). During these months, it exceeded 0.3. In July and September, it dropped below 0.23 due to upwelling which provided nutrients and a considerably different phytoplankton community to the nearshore region of Lake Michigan that was sampled. The remainder of the year it varied from 2.1 to 2.3. Redundancies for 1975 and 1976 were quite similar and show no long-term trends.

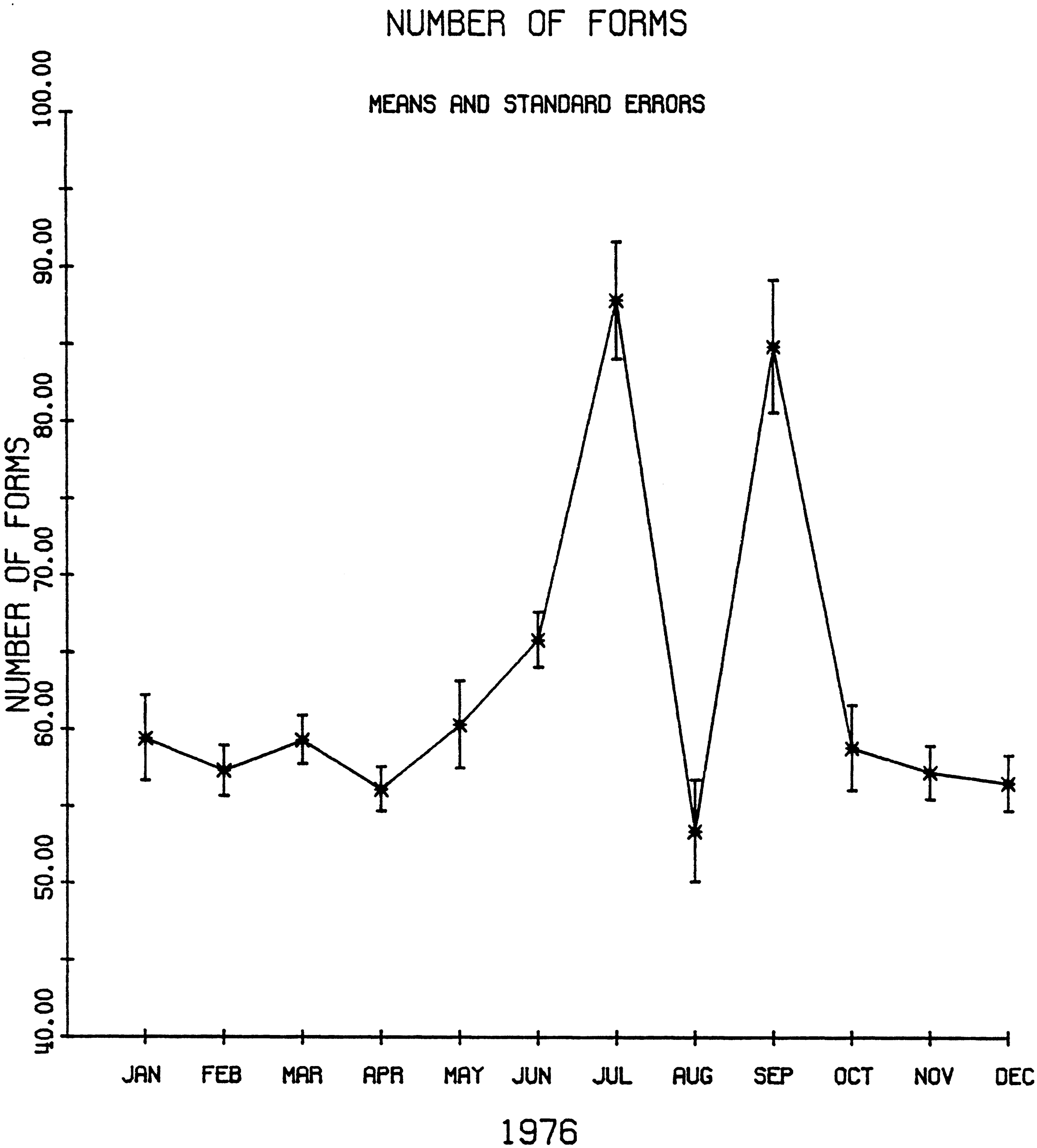

FIG. 12. Variation of number of forms of phytoplankton during 1976.

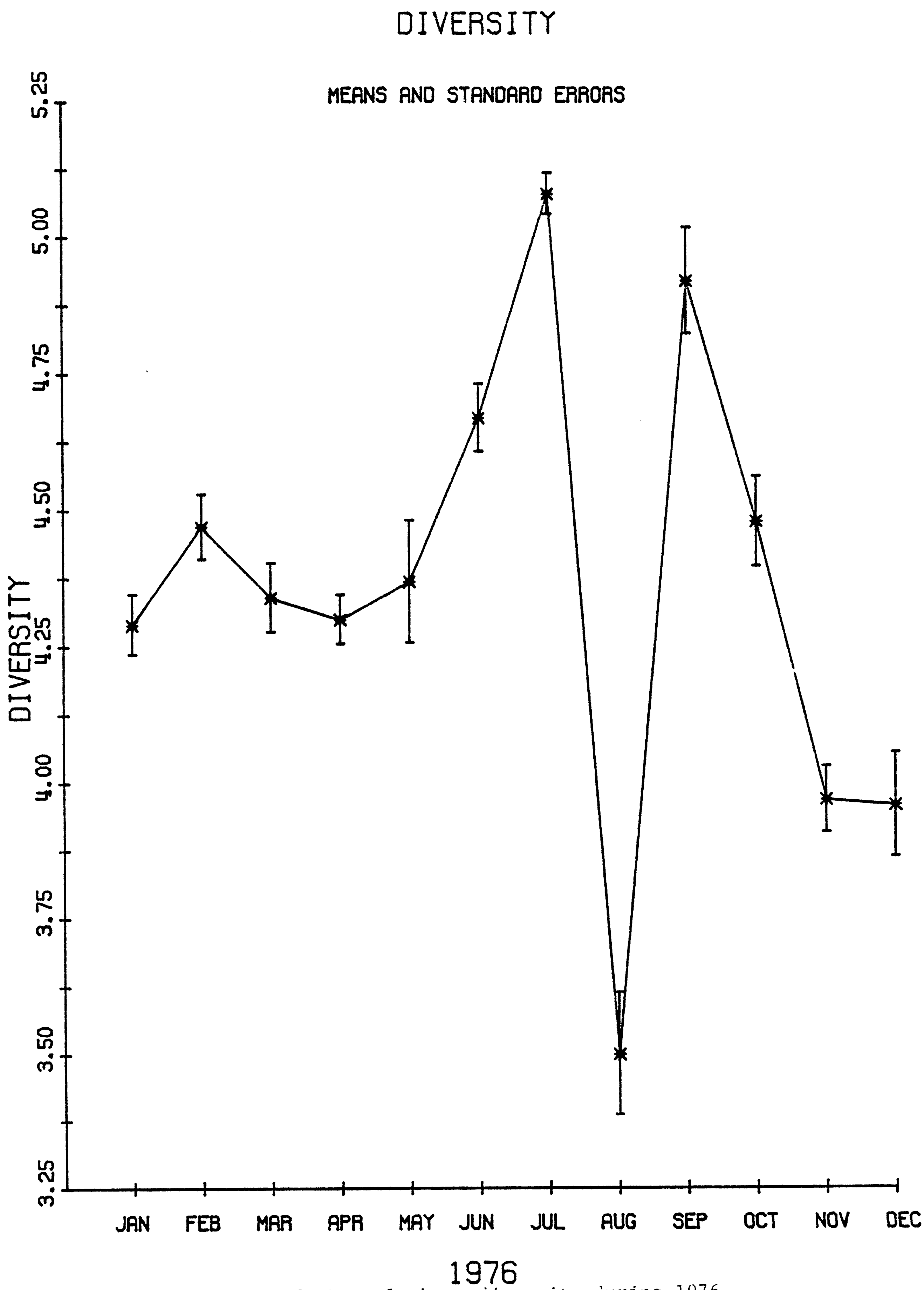

FIG. 13. Variation of phytoplankton diversity during 1976.

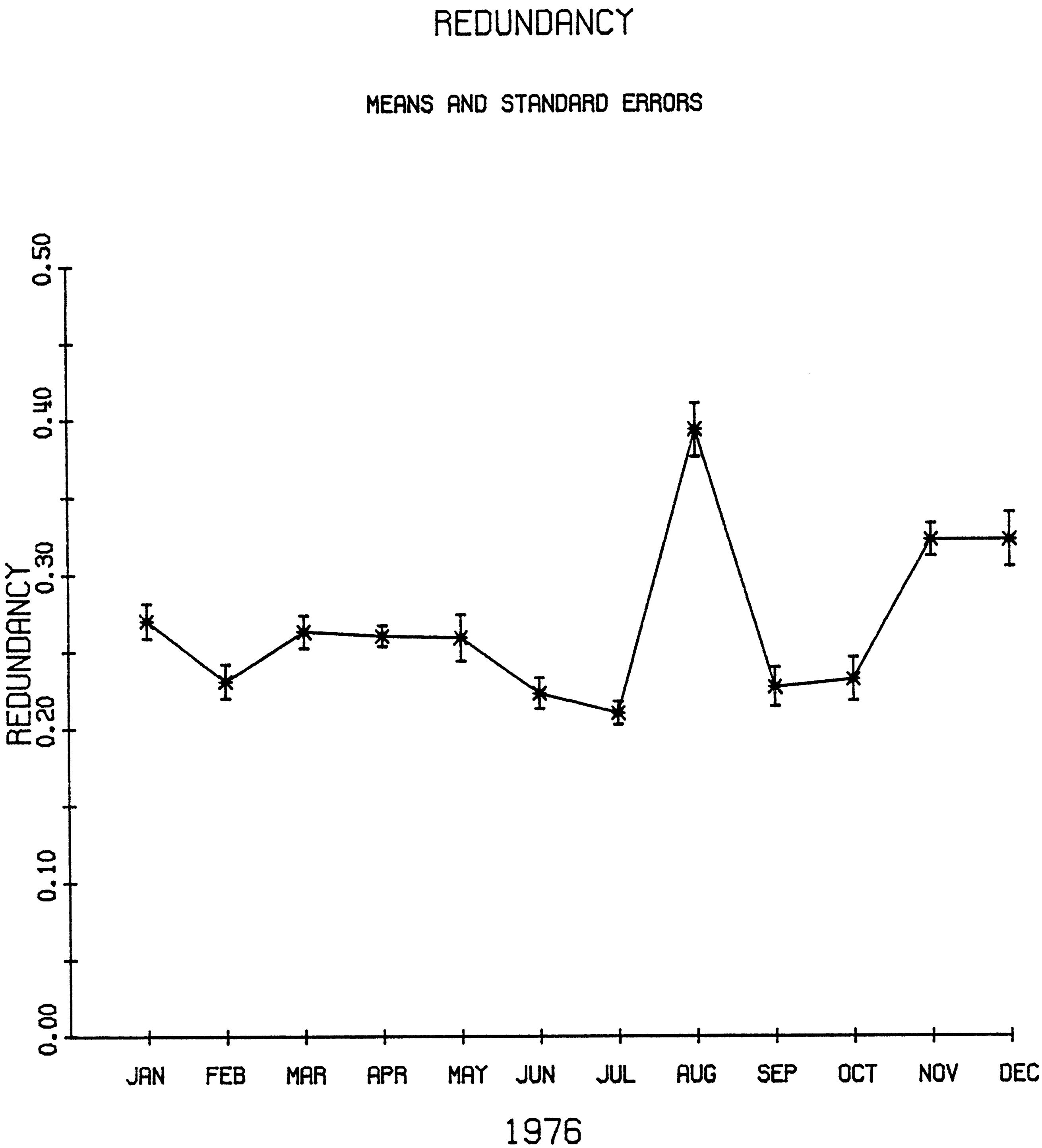

FIG. 14. Variation of phytoplankton redundancy during 1976.

TABLE 17. Number of forms of phytoplankton for 1975 and 1976.

	1975			1976		
Month	N	Mean	Standard Error	N	Mean	Standard Error
January	--	--	--	11	59.4	2.79
February	9	51.1	1.90	12	57.3	1.64
March	9	51.7	1.89	12	59.3	1.59
April	9	48.3	1.38	12	56.1	1.43
May	9	47.4	1.78	12	60.3	2.84
June	12	49.2	1.77	12	65.8	1.77
July	12	51.6	0.892	12	87.8	3.78
August	12	44.5	2.32	12	53.4	3.31
September	10	44.1	3.12	12	84.8	4.30
October	12	54.9	2.18	12	58.8	2.77
November	12	50.3	2.11	12	57.2	1.74
December	11	50.8	1.74	12	56.5	1.81

TABLE 18. Diversity of phytoplankton for 1975 and 1976.

	1975			1976		
Month	N	Mean	Standard Error	N	Mean	Standard Error
January	--	--	--	11	4.29	.0547
February	9	4.35	.0473	12	4.47	.0591
March	9	4.30	.0544	12	4.34	.0633
April	9	4.21	.0569	12	4.30	.0446
May	9	3.76	.288	12	4.37	.112
June	12	4.17	.0809	12	4.67	.0616
July	12	3.93	.0654	12	5.08	.0380
August	12	3.58	.163	12	3.50	.114
September	10	3.36	.189	12	4.92	.0973
October	12	3.96	.138	12	4.48	.0823
November	12	4.02	.199	12	3.97	.0608
December	11	3.83	.0982	12	3.96	.0963

TABLE 19. Redundancy of phytoplankton for 1975 and 1976.

	1975			1976		
Month	N	Mean	Standard Error	N	Mean	Standard Error
January	--	--	--	11	.270	.0114
February	9	.230	.00916	12	.231	.0111
March	9	.243	.00781	12	.263	.0106
April	9	.246	.00879	12	.260	.00667
May	9	.327	.0540	12	.259	.0150
June	12	.258	.00973	12	.223	.0101
July	12	.310	.0114	12	.210	.00759
August	12	.353	.0262	12	.393	.0172
September	10	.389	.0290	12	.227	.0127
October	12	.317	.0212	12	.232	.0141
November	12	.289	.0196	12	.322	.0106
December	11	.325	.0173	12	.322	.0175

Numbers and Biomass of Phytoplankton Passing Through the Plant

With only unit one operating, the plant uses roughly 2700 $m^3 min^{-1}$ for once-through cooling. Using the means of total phytoplankton densities as representative for each month, an estimate of the numbers and weight of phytoplankton passing through the plant for each month can be made (Table 20). The weight of an individual phytoplankter has been given by Ayers and Seibel (1973) as 0.57×10^{-9} gm for inshore phytoplankton. Thus 4.84×10^{18} phytoplankton cells or 2.76×10^{9} gm of phytoplankton were entrained during 1976. These quantities were similar to 4.24×10^{18} phytoplankton cells or 2.41×10^{9} gm of phytoplankton entrained in 1975. Note must be made that these calculations assumed the plant be operating 100% of the time. This is known not to be true. Since no figures of approximate percentage of phytoplankton destroyed during condenser passage are available because of little observed plant impact, no suppositions concerning removal of numbers and weights of viable phytoplankton from the inshore regions near the plant will be made.

<u>Chlorophylls and Phaeophytin *a*</u>

Chlorophyll and phaeophytin *a* data have been used 1) to monitor monthly changes in these variables with respect to observed phytoplankton densities, 2) to determine the change in these variables that would be detectable at the .05 level of significance, 3) to measure short-term sampling variations, 4) to assess immediate impact of entrainment on phytoplankton viability, and 5) to assess impact of entrainment on phytoplankton hours after entrainment. When phytoplankton pass through the plant, several possible alterations of the population's viability may occur. Among these are killing or damage to

TABLE 20. Phytoplankton entrained by the plant during 1976.

Month	Numbers Entrained	Weight Entrained, gms
January	4.25×10^{17}	2.42×10^{8}
February	1.59×10^{17}	9.06×10^{7}
March	2.22×10^{17}	1.27×10^{8}
April	3.49×10^{17}	1.99×10^{8}
May	5.45×10^{17}	3.11×10^{8}
June	1.81×10^{17}	1.03×10^{8}
July	9.57×10^{17}	5.45×10^{8}
August	3.79×10^{17}	2.16×10^{8}
September	5.89×10^{17}	3.36×10^{8}
October	3.28×10^{17}	1.87×10^{8}
November	3.60×10^{17}	2.05×10^{8}
December	3.46×10^{17}	1.97×10^{8}
TOTAL	4.84×10^{18}	2.76×10^{9}

the organism during periods of chlorination, destruction or inhibition from the mechanical and heat effects of passage, and stimulation of productivity due to increased temperatures.

Percentage of Change Detectable at the 0.05 Level of Significance

To establish the least change in each of the chlorophylls, phaeophytin *a*, and the phaeophytin *a* to chlorophyll *a* ratio that is detectable with 95% power by analysis of variance, the equation derived by Johnston (1974) from an equation of Sokal and Rohlf (1969, p. 247) was used. It is

$$\delta = \sigma\sqrt{\frac{2}{n}}\,(t_{\alpha[\nu]} + t_{2(1-P)[\nu]}) \quad \text{where}$$

δ = least detectable true difference

σ = true error standard deviation

ν = degrees of freedom of the error mean square

n = typical number of observations for each case

t = student's t

α = significance level

P = power (the desired probability that a difference will be found significant).

For α = 0.05 and P = 0.95, δ may be calculated. The calculated δ's for chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, phaeophytin *a*, and the phaeophytin *a* to chlorophyll *a* ratio based on 92 cases consisting of 3 observations each are presented in Table 21. Compared to 1975, the 1976 δ for each variable was less (Rossmann *et al.* 1977). The large changes necessary to detect an impact on the phytoplankton have led us to modify our methodology (January 1, 1977). Instead of sonification, the samples are now ground to break up the cells for extraction into 90% acetone.

TABLE 21. δ (least detectable true difference) for chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, phaeophytin *a*, and the phaeophytin *a* to chlorophyll *a* ratio.[1]

Variable	Mean	σ, True Error Standard Deviation	δ
Chlorophyll *a*	4.44	0.506	2.11
Chlorophyll *b*	0.0990	0.0209	0.430
Chlorophyll *c*	1.14	0.136	1.10
Phaeophytin *a*	0.984	0.426	1.94
Phaeophytin *a*/ Chlorophyll *a*	0.240	0.0480	0.651

[1] 0.95 probability that the differences will be significantly different at the 0.05 level.

Table 22. Sonification versus grinding for sample preparation (July 1976)

Variable	Control[1] Mean	Control[1] Standard Error	Ground[2] Mean	Ground[2] Standard Error	Sonified[3] Mean	Sonified[3] Standard Error	Student's *t*[4] Ground vs. Sonified
Chlorophyll *a*	6.14	0.214	7.37	0.269	6.05	0.160	4.22*
Chlorophyll *b*	0.398	0.0716	0.519	0.0486	0.426	0.0856	0.927
Chlorophyll *c*	1.07	0.144	1.80	0.0876	1.11	0.0393	7.18**
Phaeophytin *a*	2.20	0.460	1.92	0.134	2.10	0.139	-0.932
Phaeophytin *a*/ Chlorophyll *a*	0.364	0.0893	0.263	0.0271	0.349	0.0321	-2.05

[1]Sample extracted in 90 % acetone, 3 replicates

[2]Sample ground and extracted in 90 % acetone, 3 replicates

[3]Sample sonified and extracted in 90 % acetone, 3 replicates

[4]One star(*) is 0.05 level of significance. Two stars (**) is 0.01 level of significance.

Grinding Versus Sonification of Samples

Sonification was initially chosen as the technique to break up phytoplankton cells for extraction of the cell contents. A recent comparison between grinding and sonification for sample preparation suggests that this was the wrong choice and that the samples should be ground using a tissue grinder to break up the cells. Comparison of these sample preparation alternatives was made in both September and November of 1976. In September, three sets of samples were collected in triplicate. One set served as a control; the sample was simply extracted into 10 ml of 09% acetone. The second set was handled as normal; that is, sonification in 10 ml of 90% acetone for 45 seconds. The last set was ground for three minutes with a tissue grinder in 10 ml of 90% acetone. Table 22 contains the results of this study. Using a Student's t-test to compare the ground to sonified samples, significant differences between the two preparation methods were found. Chlorophyll *a* and chlorophyll *c* were higher in the ground sample set. This result was alarming enough to warrant a second study.

Because of the apparent incomplete extraction of the chlorophylls from samples prepared by sonification, a second set of 24 samples was collected in November 1976 to further investigate the problem. These samples were divided into six groups: 1) a control set of 6 samples with no preparation, 2) a set of 6 samples that was sonified for a period of 45 seconds in an ice bath, 3) another set of 2 samples that was sonified in an ice bath for 45 seconds and shaken vigorously, 4) a fourth set of 3 samples that was sonified for three minutes in an ice bath, 5) a set of 5 samples that was ground for three minutes, and 6) a last set of 2 samples that was ground for three minutes in an ice bath. With the hope that chlorophyll *a* and chlorophyll *c* concentrations similar to those for ground

samples could be obtained by either increasing the sonification time or by vigorous shaking, three different groups were sonified. When the first group was ground for three minutes, some of the samples warmed considerably. Because some of the chlorophyll may have been destroyed due to this heating, a second set was ground in an ice bath to prevent this problem. Table 23 contains the results of this study.

At this time, no judgment can be made about the variability of chlorophyll *b* extraction with sample handling technique because the phytoplankton possessing this chlorophyll, green algae, were not abundant when these samples were collected. The highest mean chlorophyll *a* concentrations were yielded by grinding and by sonification with shaking. Grinding increased the extractability of chlorophyll *c*. The control and the sonified (45 sec.) gave the highest phaeophytin *a* measured. Sonification with shaking and a longer sonification time decreased the amount of phaeophytin *a* extracted. The lowest phaeophytin *a* to chlorophyll *a* ratio was obtained from samples ground in an ice bath. Using a Student's t-test to determine what significant differences exist between our current technique of sonifying for 45 seconds versus our proposed technique of grinding for 3 minutes, significant (0.01 level of significance) differences between the two were found. Both chlorophyll *a* and chlorophyll *c* were extracted more completely using the grinding technique of sample preparation. Differences between these two sets of samples is believed to result from incomplete destruction of diatom tests and release of cell contents during sonification and from preferential extraction of cell contents from dead or dying phytoplankton when the samples are sonified. Because of these results, samples will be ground beginning in January 1977. This is warranted

TABLE 23. Grinding versus sonification for sample preparation (November 1976).

Variable	Control[1]		Sonified (45sec)[2]		Sonified & Shaken (45sec)[3]		Sonified (3min)[4]		Ground (3min)[5]		Ground in Ice Bath (3min)[6]		Student's t[7]
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Ground (3min) vs. Sonified (45sec)
Chlorophyll *a*	2.88	0.143	2.62	0.154	3.45	0.0900	3.07	0.151	3.69	0.102	3.71	0.0100	-5.51**
Chlorophyll *b*	0.0376	0.0242	0.	0.	0.	0.	0.	0.	0.0206	0.0123	0.	0.	-
Chlorophyll *c*	0.494	0.0977	0.484	0.0709	0.590	0.0685	0.455	0.128	0.902	0.100	0.920	0.0385	-3.49**
Phaeophytin *a*	0.977	0.168	1.20	0.241	0.408	0.139	0.406	0.0883	0.632	0.159	0.356	0.0960	1.89
Phaeophytin *a*/ Chlorophyll *a*	0.352	0.0684	0.489	0.122	0.120	0.0435	0.130	0.0235	0.176	0.0469	0.0530	0.0141	2.22

1 6 replicates

2 6 replicates

3 2 replicates

4 3 replicates

5 5 replicates

6 2 replicates

7 One star (*) = 0.05 level of significance. Two stars (**) = 0.01 level of significance.

because a greater and more consistent recovery of the chlorophylls and less degradation of chlorophyll *a* to phaeophytin *a* will be obtained. This will permit a more accurate assessment of phytoplankton viability. Additional comparisons between sonified samples and samples ground will be made to more completely document this extraction problem.

Time Variation of Samples

Eighteen samples were collected in the intake forebay during a five-minute time span to investigate whether or not significant natural variations in phytoplankton viability occurred during sampling due to patchiness of the phytoplankton. These were collected in July 1976. These samples were arranged into six groups of three consecutive samples, yielding six cases.

Figures 15 through 19 summarize the variability of the six cases representing the collection time span of five minutes. Standard error bars are associated with each mean. For chlorophyll *a*, case 3 was lower than case 1. Chlorophyll *b* for case 1 was relatively low. Chlorophyll *c* for case 3 was lower than that of case 5. Phaeophytin *a* and the phaeophytin *a*/chlorophyll *a* ratio were lower for case 1 relative to cases 5 and 6. Therefore, within a five-minute time period, it was possible to collect two groups of samples that were different. This illustrates that heterogeneity can exist in samples collected during our normal 15 to 30-minute collection period in the intake and discharge forebays.

Assessment of Damage to Phytoplankton

Results of monthly sampling for chlorophyll analyses are found in Tables 24 through 28. Those times when chlorophyll *a* was significantly

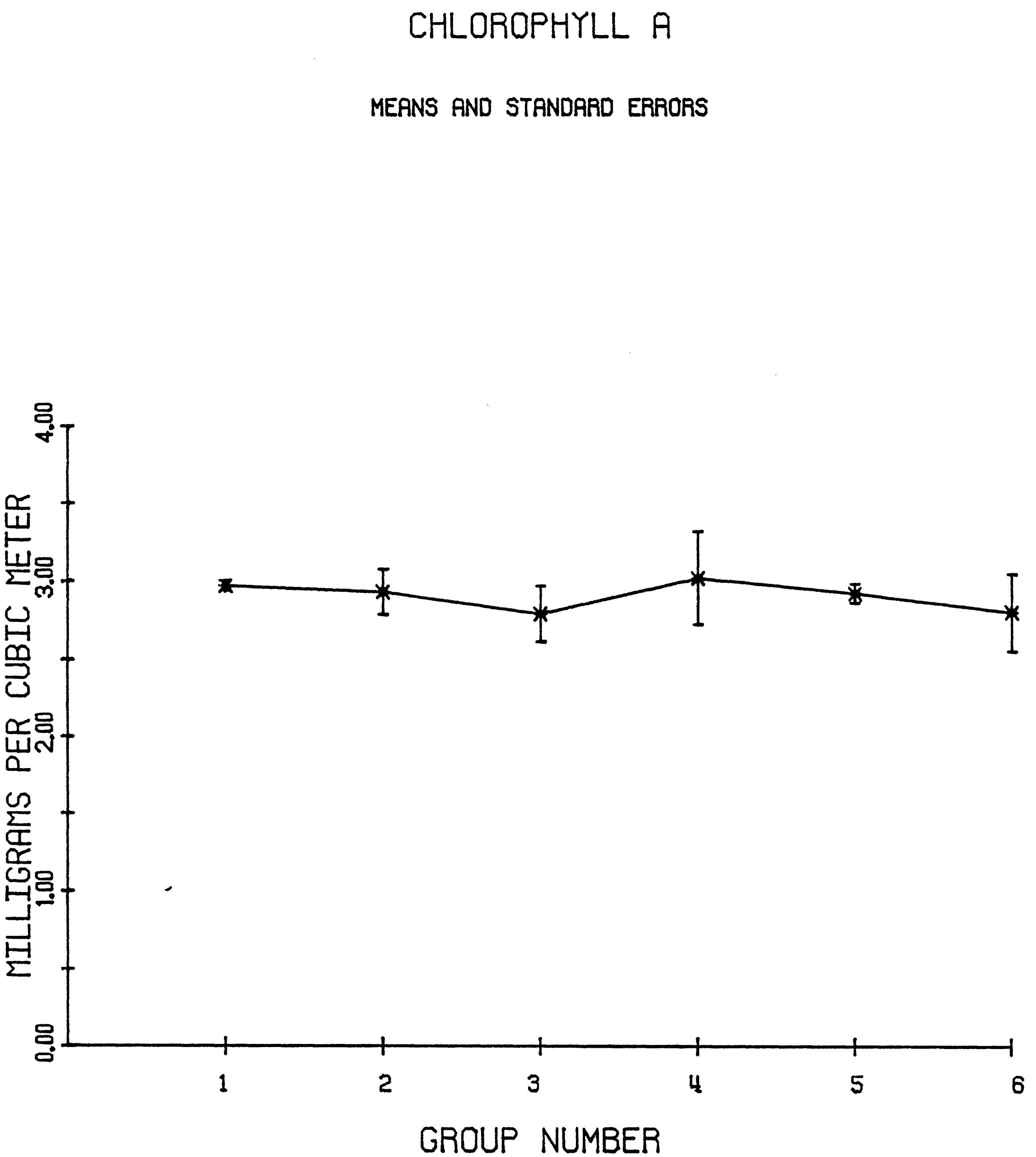

FIG. 15. Chlorophyll *a* concentrations measured in 6 groups of 3 consecutive samples, formed from a set of 18 samples drawn in succession from the intake forebay during a 5-minute period.

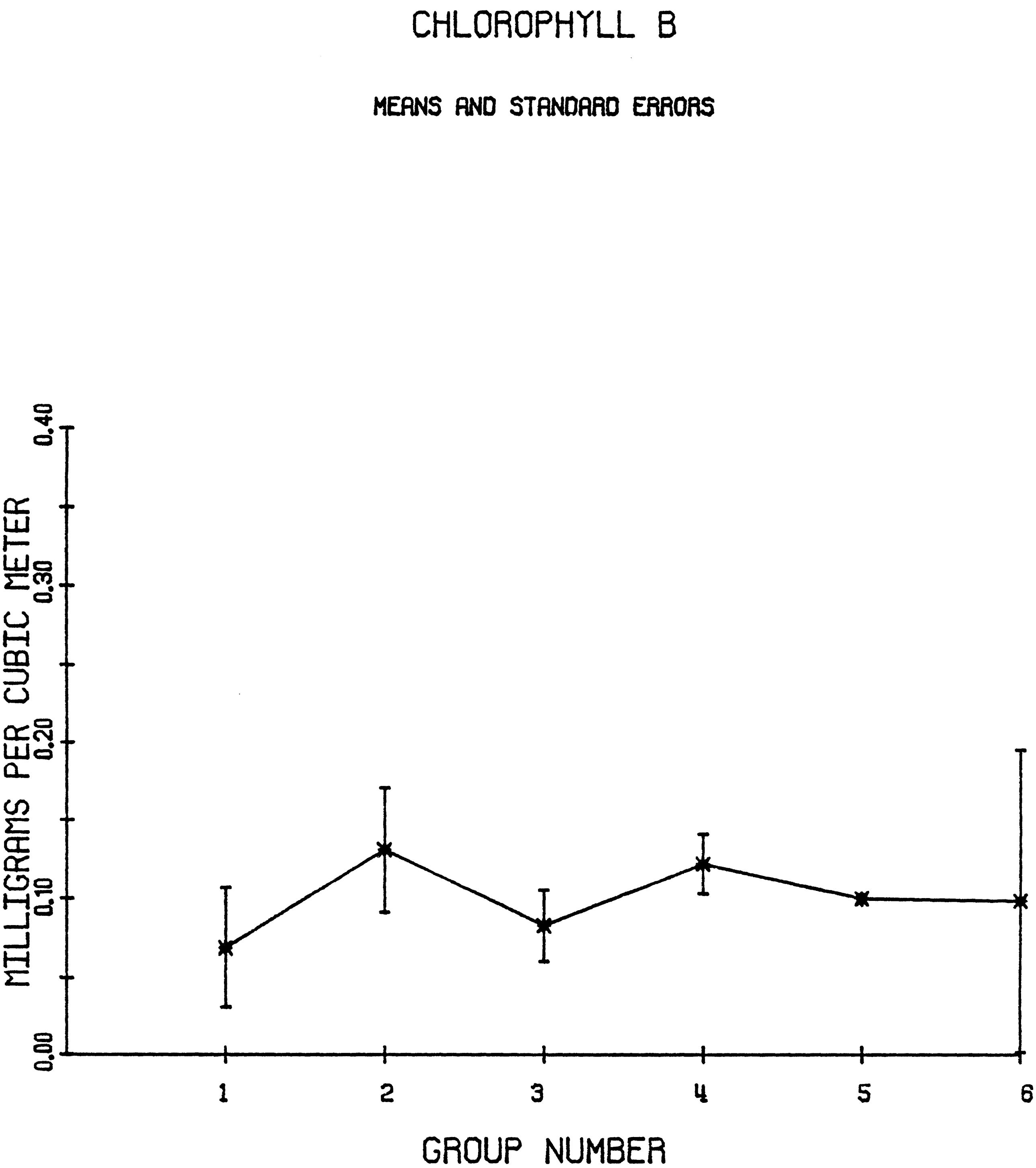

FIG. 16. Chlorophyll *b* concentrations measured in 6 groups of 3 consecutive samples, formed from a set of 18 samples drawn in succession from the intake forebay during a 5-minute period.

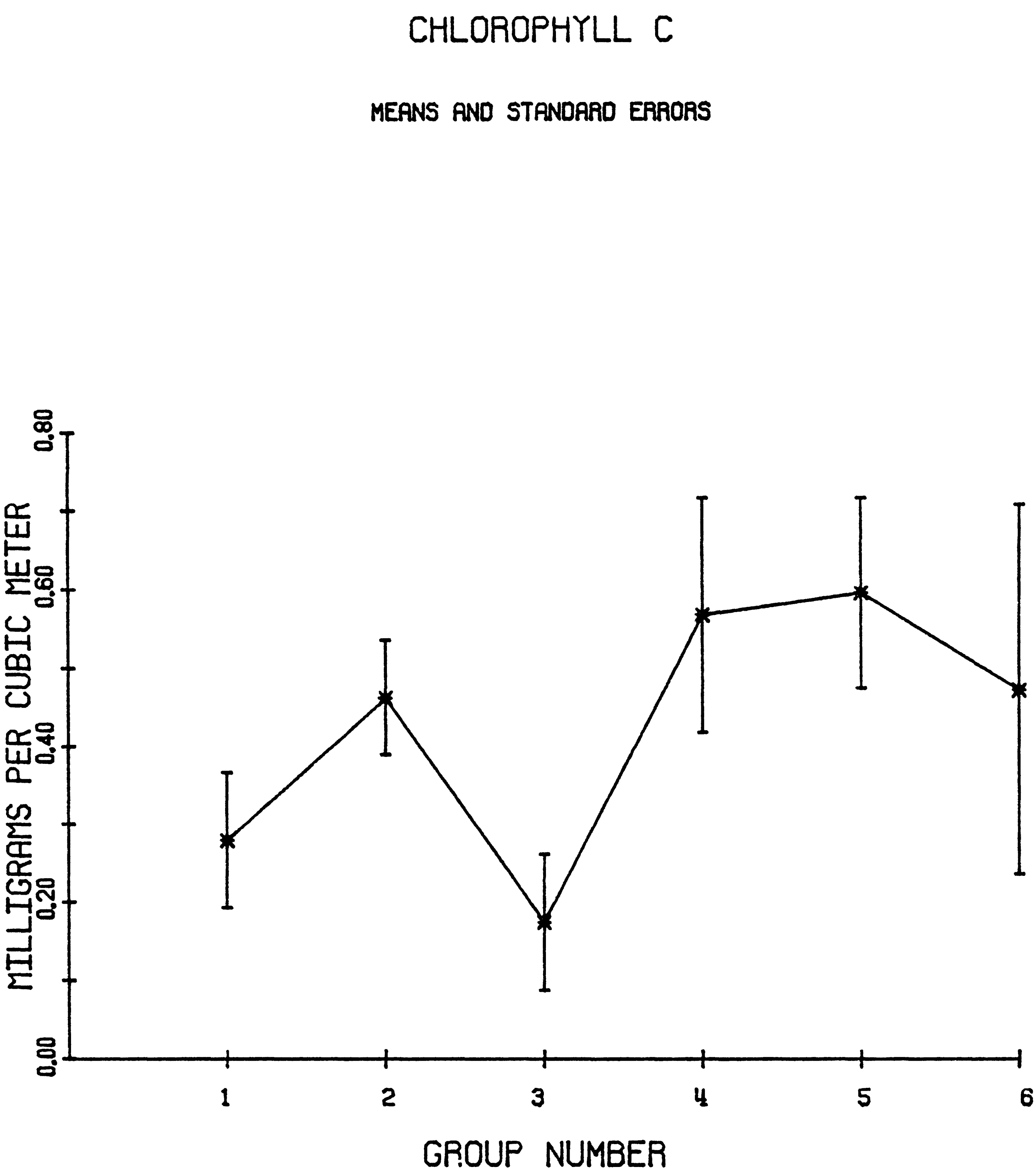

FIG. 17. Chlorophyll *c* concentrations measured in 6 groups of 3 consecutive samples, formed from a set of 18 samples drawn from the intake forebay during a 5-minute period.

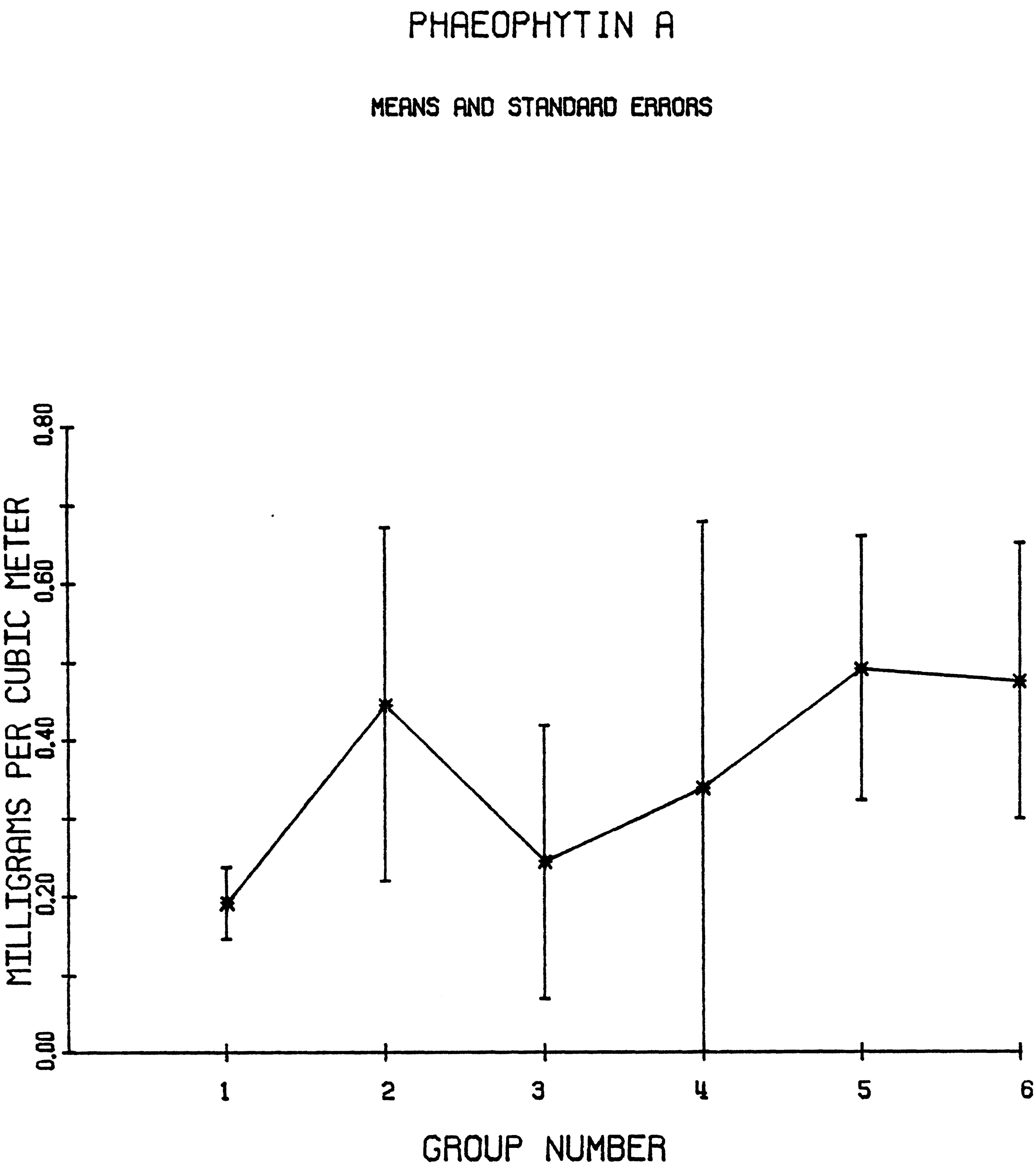

FIG. 18. Phaeophytin *a* concentrations measured in 6 groups of 3 consecutive samples, formed from a set of 18 samples drawn in succession from the intake forebay during a 5-minute period.

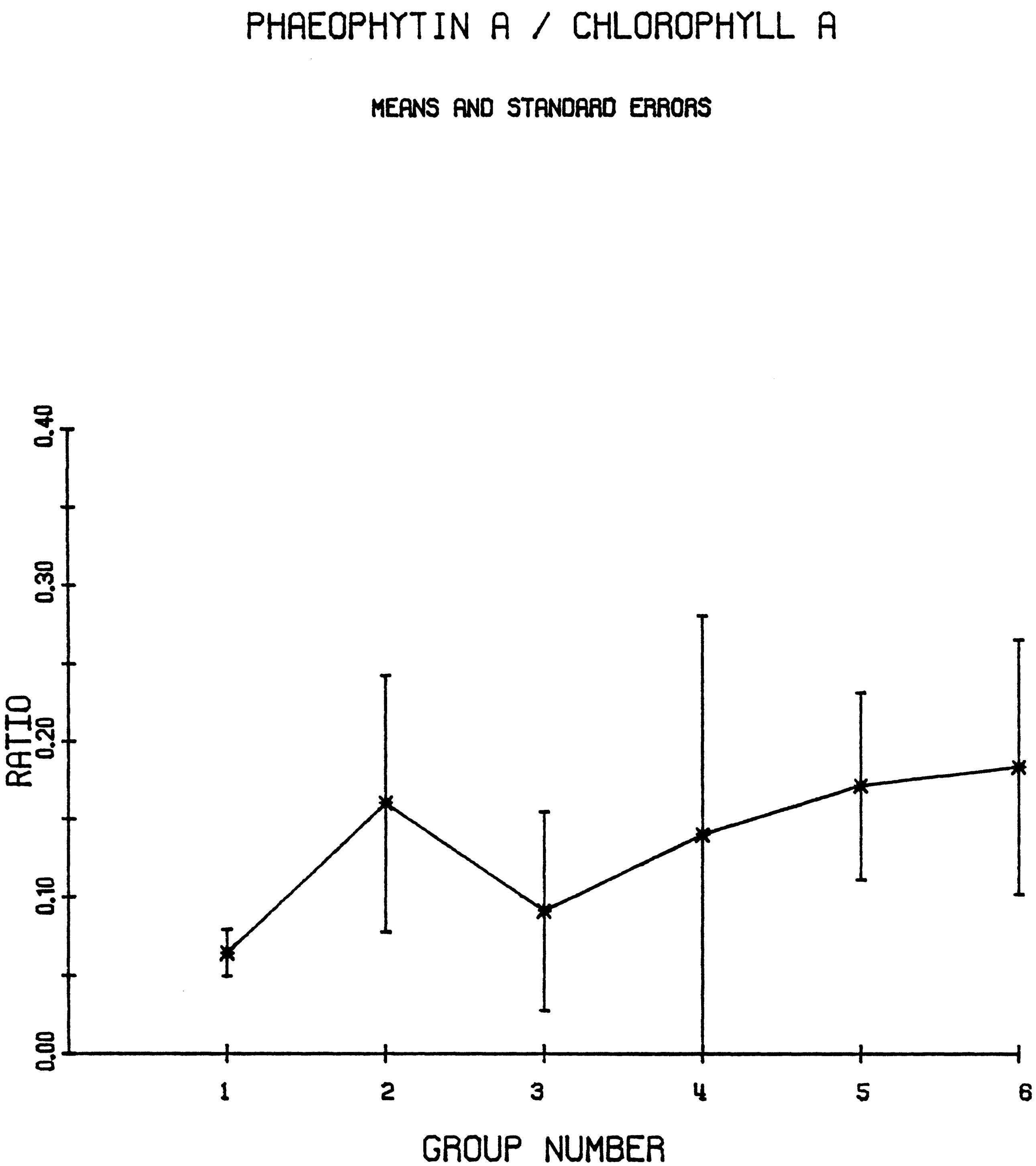

FIG. 19. Variation of the phaeophytin *a* to chlorophyll *a* ratio during a 5-minute sampling period for 6 groups of 3 consecutive samples, formed from a set of 18 samples drawn in succession from the intake forebay.

TABLE 24. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/13/76	1945	I5	0	3	0.313E+01	0.282E+00	INTAKE VS. DISCHARGE	0.112E+01	0.351E+00
01/13/76	1945	D	0	3	0.3[illegible]1E+01	0.578E+00			
01/13/76	1945	I5	38	3	0.506E+01	0.860E+00	INTAKE VS. DISCHARGE	0.127E+01	0.324E+00
01/13/76	1945	D	38	3	0.408E+01	0.120E+00			
01/14/76	0630	I5	0	3	0.586E+01	0.399E+00	INTAKE VS. DISCHARGE	0.479E+01	0.959E-01
01/14/76	0630	D	0	3	0.343E+01	0.104E+01			
01/14/76	1245	I5	0	3	0.395E+01	0.597E+00	INTAKE VS. DISCHARGE	0.313E+00	0.605E+00
01/14/76	1245	D	0	3	0.361E+01	0.111E+00			
02/10/76	2000	I5	0	3	0.271E+01	0.451E-01	INTAKE VS. DISCHARGE	0.343E+00	0.590E+00
02/10/76	2000	D	0	3	0.265E+01	0.982E-01			
02/10/76	2000	I5	38	3	0.216E+01	0.356E+00	INTAKE VS. DISCHARGE	0.173E+01	0.260E+00
02/10/76	2000	D	38	3	0.343E+01	0.903E+00			
02/11/76	0600	I5	0	3	0.206E+01	0.108E+00	INTAKE VS DISCHARGE	0.178E+00	0.690E+00
02/11/76	0600	D	0	3	0.214E+01	0.165E+00			
02/11/76	1215	I5	0	3	0.177E+01	0.240E-01	INTAKE VS. DISCHARGE	0.905E+01	0.421E-01
02/11/76	1215	D	0	3	0.204E+01	0.888E-01			
03/09/76	2030	I5	0	3	0.254E+01	0.121E+00	INTAKE VS. DISCHARGE	0.143E+00	0.718E+00
03/09/76	2030	D	0	3	0.245E+01	0.215E+00			
03/09/76	2030	I5	36	3	0.240E+01	0.307E+00	INTAKE VS. DISCHARGE	0.216E+00	0.663E+00
03/09/76	2030	D	36	3	0.222E+01	0.237E+00			
03/10/76	0505	I5	0	3	0.180E+01	0.147E+00	INTAKE VS. DISCHARGE	0.318E+01	0.151E+00
03/10/76	0505	D	0	3	0.225E+01	0.205E+00			
03/10/76	1218	I5	0	3	0.201E+01	0.171E+00	INTAKE VS. DISCHARGE	0.599E+00	0.485E+00
03/10/76	1218	D	0	3	0.218E+01	0.131E+00			
04/05/76	2101	I5	0	3	0.619E+01	0.104E+00	INTAKE VS. DISCHARGE	0.120E+01	0.336E+00
04/05/76	2101	D	0	3	0.588E+01	0.263E+00			
04/05/76	2101	I5	36	3	0.443E+01	0.114E+00	INTAKE VS. DISCHARGE	0.137E+01	0.308E+00
04/05076	2101	D	36	3	0.392E+01	0.418E+00			
04/06/76	0600	I5	0	3	0.571E+01	0.621E+00	INTAKE VS. DISCHARGE	0.903E+00	0.398E+00
04/06/76	0600	D	0	3	0.511E+01	0.113E+00			
04/06/76	1200	I5	0	3	0.489E+01	0.568E+00	INTAKE VS. DISCHARGE	0.940E-01	0.764E+00
04/06/76	1200	D	0	3	0.508E+01	0.247E+00			

TABLE 24. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
05/10/76	2120	I5 0	3	0.792E+01	0.365E+00			
05/10/76	2120	D 0	3	0.725E+01	0.470E+00	INTAKE VS. DISCHARGE	0.128E+01	0.323E+00
05/10/76	2120	I5 34	2	0.460E+01	0.605E+00			
05/10/76	2120	D 34	3	0.550E+01	0.776E+00	INTAKE VS. DISCHARGE	0.669E+00	0.475E+00
05/11/76/	0330	I5 0	3	0.104E+02	0.903E+00			
05/11/76	0330	D 0	3	0.855E+01	0.702E+00	INTAKE VS. DISCHARGE	0.268E+01	0.178E+00
05/11/76	1200	I5 0	3	0.737E+01	0.618E+00			
05/11/76	1200	D C	3	0.117E+02	0.156E+01	INTAKE VS. DISCHARGE	0.679E+01	0.620E-01
06/14/76	2240	I5 0	3	0.299E+01	0.113E+00			
06/14/76	2240	D 0	3	0.216E+01	0.358E+00	INTAKE VS. DISCHARGE	0.496E+01	0.920E-01
06/14/76	2240	I5 33	3	0.270E+01	0.114E+00			
06/14/76	2240	D 33	3	0.179E+01	0.514E+00	INTAKE VS. DISCHARGE	0.296E+01	0.162E+00
06/15/76	0330	I5 0	3	0.323E+01	0.295E+00			
06/15/76	0330	D 0	3	0.275E+01	0.116E+00	INTAKE VS. DISCHARGE	0.229E+01	0.206E+00
06/15/76	1110	I5 0	3	0.358E+01	0.262E+00			
06/15/76	1110	D 0	3	0.309E+01	0.888E-01	INTAKE VS. DISCHARGE	0.314E+01	0.152E+00
07/12/76	2250	I5 0	3	0.121E+02	0.736E+00			
07/12/76	2250	D 0	3	0.122E+02	0.114E+01	INTAKE VS. DISCHARGE	0.578E-02	0.932E+00
07/12/76	2250	I5 37	3	0.117E+02	0.656E+00			
07/12/76	2250	D 37	3	0.990E+01	0.469E+00	INTAKE VS. DISCHARGE	0.498E+01	0.915E-01
07/13/76I5	0355	0	2	0.101E+02	0.305E+00			
07/13/76	0355	D 0	3	0.105E+02	0.840E+00	INTAKE VS. DISCHARGE	0.154E+00	0.714E+00
07/13/76	1235	I5 0	3	0.733E+01	0.332E+00			
07/13/76	1235	D 0	3	0.709E+01	0.349E+00	INTAKE VS. DISCHARGE	0.248E+00	0.643E+00
08/09/76	2145	I5 0	3	0.322E+01	0.689E-01			
08/09/76	2145	D 0	3	0.294E+01	0.617E-01	INTAKE VS. DISCHARGE	0.961E+01	0.388E-01
08/09/76	2145	I5 36	3	0.303E+01	0.116E+00			
08/09/76	2145	D 36	3	0.219E+01	0.132E+00	INTAKE VS. DISCHARGE	0.233E+02	0.109E-01
08/10/76	0355	I5 0	3	0.455E+01	0.153E+00			
08/10/76	0355	D 0	3	0.395E+01	0.110E+00	INTAKE VS. DISCHARGE	0.102E+02	0.355E-01
08/10/76	1205	I5 0	3	0.402E+01	0.181E+00			
08/10/76	1205	D 0	3	0.298E+01	0.175E+00	INTAKE VS. DISCHARGE	0.171E+02	0.170E-01

TABLE 24. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
09/22/76	2145	I5 0	3	0.376E+01	0.186E+00			
09/22/76	2145	D 0	3	0.349E+01	0.418E-01	INTAKE VS. DISCHARGE	0.196E+01	0.235E+00
09/22/76	2145	I5 38	2	0.259E+01	0.250E-01			
09/22/76	2145	D 38	3	0.250E+01	0.191E+00	INTAKE VS. DISCHARGE	0.128E+00	0.736E+00
09/23/76	0610	I5 0	3	0.468E+01	0.184E+00			
09/23/76	0610	D 0	3	0.422E+01	0.254E+00	INTAKE VS. DISCHARGE	0.212E+01	0.221E+00
09/23/76	1145	I5 0	3	0.618E+01	0.147E+00			
09/23/76	1145	D 0	2	0.548E+01	0.590E+00	INTAKE VS. DISCHARGE	0.212E+01	0.243E+00
10/11/76	2040	I5 0	3	0.340E+01	0.601E-01			
10/11/76	2040	D 0	3	0.302E+01	0.237E+00	INTAKE VS. DISCHARGE	0.237E+01	0.200E+00
10/11/76	2040	I5 38	3	0.292E+01	0.199E+00			
10/11/76	2040	D 38	3	0.279E+01	0.407E+00	INTAKE VS. DISCHARGE	0.823E-01	0.777E+00
10/12/76	0630	I5 0	3	0.388E+01	0.236E+00			
10/12/76	0630	D 0	3	0.310E+01	0.269E+00	INTAKE VS. DISCHARGE	0.475E+01	0.969E-01
10/12/76	1220	I5 0	3	0.391E+01	0.101E+00			
10/12/76	1220	D 0	3	0.386E+01	0.219E+00	INTAKE VS. DISCHARGE	0.429E-01	0.832E+00
11/08/76	1900	I5 0	3	0.334E+01	0.162E+00			
11/08/76	1900	D 0	3	0.326E+01	0.171E+00	INTAKE VS. DISCHARGE	0.115E+00	0.742E+00
11/08/76	1900	I5 41	3	0.304E+01	0.590E-01			
11/08/76	1900	D 41	3	0.260E+01	0.154E+00	INTAKE VS. DISCHARGE	0.692E+01	0.605E-01
11/09/76	0810	I5 0	3	0.317E+01	0.138E+00			
11/09/76	0810	D 0	3	0.279E+01	0.513E-01	INTAKE VS. DISCHARGE	0.680E+01	0.619E-01
11/09/76	1310	I5 0	3	0.306E+01	0.441E-01			
11/09/76	1310	D 0	3	0.400E+01	0.113E+00	INTAKE VS. DISCHARGE	0.596E+02	0.318E-02
12/15/76	1920	I5 0	3	0.477E+01	0.865E-01			
12/15/76	1920	D 0	3	0.418E+01	0.314E+00	INTAKE VS. DISCHARGE	0.332E+01	0.144E+00
12/15/76	1920	I5 36	3	0.500E+01	0.286E+00			
12/15/76	1920	D 36	3	0.498E+01	0.101E+00	INTAKE VS. DISCHARGE	0.434E-02	0.940E+00
12/16/76	0720	I5 0	3	0.527E+01	0.253E+00			
12/16/76	0720	D 0	3	0.503E+01	0.119E+00	INTAKE VS. DISCHARGE	0.695E+00	0.454E+00
12/16/76	1315	I5 0	3	0.585E+01	0.143E+00			
12/16/76	1315	D 0	3	0.574E+01	0.590E-01	INTAKE VS. DISCHARGE	0.446E+00	0.543E+00

TABLE 25. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/13/76	1945	I5	0	3	0.430E-01	0.216E-01			
01/13/76	1945	D	0	3	0.940E-01	0.501E-01	INTAKE VS. DISCHARGE	0.875E+00	0.405E+00
01/13/76	1945	I5	38	3	0.137E-01	0.137E-01			
01/13/76	1945	D	38	3	0.100E-10	0.613E-17	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
01/14/76	0630	I5	0	3	0.146E+00	0.945E-01			
01/14/76	0630	D	0	3	0.210E+00	0.142E+00	INTAKE VS. DISCHARGE	0.140E+00	0.721E+00
01/14/76	1245	I5	0	3	0.100E-10	0.613E-17			
01/14/76	1245	D	0	3	0.209E-01	0.209E-01	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
02/10/76	2000	I5	0	3	0.394E-01	0.199E-01			
02/10/76	2000	D	0	3	0.112E+00	0.307E-01	INTAKE VS. DISCHARGE	0.397E+01	0.119E+00
02/10/76	2000	I5	38	3	0.358E-01	0.294E-01			
02/10/76	2000	D	38	3	0.127E+00	0.392E-01	INTAKE VS. DISCHARGE	0.343E+01	0.139E+00
02/11/76	0600	I5	0	3	0.293E-01	0.293E-01			
02/11/76	0600	D	0	3	0.420E-01	0.220E-01	INTAKE VS DISCHARGE	0.120E+00	0.738E+00
02/11/76	1215	I5	0	3	0.122E-01	0.122E-01			
02/11/76	1215	D	0	3	0.804E-01	0.424E-01	INTAKE VS. DISCHARGE	0.239E+01	0.198E+00
03/09/76	2030	I5	0	3	0.106E+00	0.842E-01			
03/09/76	2030	D	0	3	0.980E-02	0.520E-02	INTAKE VS. DISCHARGE	0.129E+01	0.320E+00
03/09/76	2030	I5	36	3	0.180E-01	0.180E-01			
03/09/76	2030	D	36	3	0.100E-10	0.613E-17	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
03/10/76	0505	I5	0	3	0.357E-01	0.357E-01			
03/10/76	0505	D	0	3	0.340E-01	0.340E-01	INTAKE VS. DISCHARGE	0.114E-02	0.964E+00
03/10/76	1218	I5	0	3	0.200E-01	0.188E-01			
03/10/76	1218	D	0	3	0.328E-01	0.168E-01	INTAKE VS. DISCHARGE	0.257E+00	0.637E+00
04/05/76	2101	I5	0	3	0.667E-11	0.333E-11			
04/05/76	2101	D	0	3	0.667E-11	0.333E-11	INTAKE VS. DISCHARGE	0.0	0.100E+01
04/05/76	2101	I5	36	3	0.912E-01	0.787E-01			
04/05076	2101	D	36	3	0.158E+00	0.118E+00	INTAKE VS. DISCHARGE	0.219E+00	0.661E+00
04/06/76	0600	I5	0	3	0.208E+00	0.142E+00			
04/06/76	0600	D	0	3	0.667E-11	0.333E-11	INTAKE VS. DISCHARGE	0.215E+01	0.217E+00
04/06/76	1200	I5	0	3	0.173E-01	0.173E-01			
04/06/76	1200	D	0	3	0.230E-03	0.230E-03	INTAKE VS. DISCHARGE	0.974E+00	0.382E+00

TABLE 25. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
05/10/76	2120	I5 0	3	0.103E+00	0.542E-01			
05/10/76	2120	D 0	3	0.148E-01	0.758E-02	INTAKE VS. DISCHARGE	0.259E+01	0.184E+00
05/10/76	2120	I5 34	2	0.132E+00	0.132E+00			
05/10/76	2120	D 34	3	0.305E+00	0.610E-01	INTAKE VS. DISCHARGE	0.186E+01	0.268E+00
05/11/76/	0330	I5 0	3	0.168E+00	0.842E-01			
05/11/76	0330	D 0	3	0.933E+00	0.609E+00	INTAKE VS. DISCHARGE	0.155E+01	0.282E+00
05/11/76	1200	I5 0	3	0.304E+00	0.210E+00			
05/11/76	1200	D 0	3	0.208E+00	0.818E-01	INTAKE VS. DISCHARGE	0.182E+00	0.687E+00
06/14/76	2240	I5 0	3	0.667E-11	0.333E-11			
06/14/76	2240	D 0	3	0.667E-11	0.333E-11	INTAKE VS. DISCHARGE	0.0	0.100E+01
06/14/76	2240	I5 33	3	0.914E-01	0.546E-01			
06/14/76	2240	D 33	3	0.120E+00	0.919E-01	INTAKE VS. DISCHARGE	0.737E-01	0.787E+00
06/15/76	0330	I5 0	3	0.667E-11	0.333E-11			
06/15/76	0330	D 0	3	0.100E-10	0.613E-17	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
06/15/76	1110	I5 0	3	0.100E-10	0.613E-17			
06/15/76	1110	D 0	3	0.100E-10	0.613E-17	INTAKE VS. DISCHARGE	0.0	0.100E+01
07/12/76	2250	I5 0	3	0.542E+00	0.398E-01			
07/12/76	2250	D 0	3	0.341E+00	0.108E+00	INTAKE VS. DISCHARGE	0.304E+01	0.158E+00
07/12/76	2250	I5 37	3	0.370E+00	0.153E+00			
07/12/76	2250	D 37	3	0.518E+00	0.116E+00	INTAKE VS. DISCHARGE	0.591E+00	0.487E+00
07/13/76I5	0355	0	2	0.207E+00	0.109E+00			
07/13/76	0355	D 0	3	0.430E-01	0.215E-01	INTAKE VS. DISCHARGE	0.368E+01	0.153E+00
07/13/76	1235	I5 0	3	0.192E+00	0.413E-01			
07/13/76	1235	D 0	3	0.198E+00	0.474E-01	INTAKE VS. DISCHARGE	0.101E-01	0.912E+00
08/09/76	2145	I5 0	3	0.338E-01	0.229E-01			
08/09/76	2145	D 0	3	0.382E-01	0.195E-01	INTAKE VS. DISCHARGE	0.212E-01	0.877E+00
08/09/76	2145	I5 36	3	0.540E-02	0.540E-02			
08/09/76	2145	D 36	3	0.509E-01	0.471E-01	INTAKE VS. DISCHARGE	0.922E+00	0.393E+00
08/10/76	0355	I5 0	3	0.100E-10	0.613E-17			
08/10/76	0355	D 0	3	0.138E+00	0.618E-01	INTAKE VS. DISCHARGE	0.497E+01	0.918E-01
08/10/76	1205	I5 0	3	0.111E+00	0.394E-01			
08/10/76	1205	D 0	3	0.219E-01	0.219E-01	INTAKE VS. DISCHARGE	0.394E+01	0.120E+00

TABLE 25. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
09/22/76	2145	I5 0	3	0.248E-01	0.184E-01			
09/22/76	2145	D 0	3	0.773E-01	0.417E-01	INTAKE VS. DISCHARGE	0.133E+01	0.315E+00
09/22/76	2145	I5 38	2	0.486E-01	0.251E-01			
09/22/76	2145	D 38	3	0.102E+00	0.571E-02	INTAKE VS. DISCHARGE	0.701E+01	0.790E-01
09/23/76	0610	I5 0	3	0.291E+00	0.358E-01			
09/23/76	0610	D 0	3	0.179E+00	0.417E-01	INTAKE VS. DISCHARGE	0.413E+01	0.114E+00
09/23/76	1145	I5 0	3	0.281E+00	0.247E-01			
09/23/76	1145	D 0	2	0.266E+00	0.595E-01	INTAKE VS. DISCHARGE	0.705E-01	0.795E+00
10/11/76	2040	I5 0	3	0.621E-01	0.364E-01			
10/11/76	2040	D 0	3	0.509E-01	0.355E-01	INTAKE VS. DISCHARGE	0.482E-01	0.823E+00
10/11/76	2040	I5 38	3	0.140E+00	0.704E-01			
10/11/76	2040	D 38	3	0.540E-01	0.540E-01	INTAKE VS. DISCHARGE	0.939E+00	0.389E+00
10/12/76	0630	I5 0	3	0.776E-01	0.605E-02			
10/12/76	0630	D 0	3	0.633E-01	0.575E-01	INTAKE VS. DISCHARGE	0.615E-01	0.803E+00
10/12/76	1220	I5 0	3	0.164E+00	0.882E-02			
10/12/76	1220	D 0	3	0.124E+00	0.271E-01	INTAKE VS. DISCHARGE	0.190E+01	0.242E+00
11/08/76	1900	I5 0	3	0.146E-01	0.146E-01			
11/08/76	1900	D 0	3	0.118E+00	0.266E-01	INTAKE VS. DISCHARGE	0.116E+02	0.297E-01
11/08/76	1900	I5 41	3	0.100E-10	0.613E-17			
11/08/76	1900	D 41	3	0.563E-02	0.563E-02	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
11/09/76	0810	I5 0	3	0.240E-01	0.125E-01			
11/09/76	0810	D 0	3	0.530E-02	0.530E-02	INTAKE VS. DISCHARGE	0.190E+01	0.241E+00
11/09/76	1310	I5 0	3	0.136E-02	0.136E-02			
11/09/76	1310	D 0	3	0.100E-10	0.613E-17	INTAKE VS. DISCHARGE	0.100E+01	0.376E+00
12/15/76	1920	I5 0	3	0.557E-01	0.367E-01			
12/15/76	1920	D 0	3	0.303E+00	0.520E-01	INTAKE VS. DISCHARGE	0.151E+02	0.204E-01
12/15/76	1920	I5 36	3	0.125E+00	0.673E-01			
12/15/76	1920	D 36	3	0.630E-02	0.630E-02	INTAKE VS. DISCHARGE	0.307E+01	0.156E+00
12/16/76	0720	I5 0	3	0.743E-01	0.743E-01			
12/16/76	0720	D 0	3	0.188E-01	0.188E-01	INTAKE VS. DISCHARGE	0.524E+00	0.511E+00
12/16/76	1315	I5 0	3	0.463E-01	0.463E-01			
12/16/76	1315	D 0	3	0.357E-02	0.357E-02	INTAKE VS. DISCHARGE	0.847E+00	0.412E+00

TABLE 26. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/13/76	1945	I5	0	3	0.180E+01	0.123E+00			
01/13/76	1945	D	0	3	0.196E+01	0.167E+00	INTAKE VS. DISCHARGE	0.597E+00	0.486E+00
01/13/76	1945	I5	38	3	0.191E+01	0.970E-01			
01/13/76	1945	D	38	3	0.142E+01	0.219E-01	INTAKE VS. DISCHARGE	0.243E+02	0.103E-01
01/14/76	0630	I5	0	3	0.296E+01	0.583E+00			
01/14/76	0630	D	0	3	0.245E+01	0.255E+00	INTAKE VS. DISCHARGE	0.633E+00	0.473E+00
01/14/76	1245	I5	0	3	0.171E+01	0.429E+00			
01/14/76	1245	D	0	3	0.223E+01	0.524E-01	INTAKE VS. DISCHARGE	0.141E+01	0.302E+00
02/10/76	2000	I5	0	3	0.113E+01	0.138E+00			
02/10/76	2000	D	0	3	0.120E+01	0.160E+00	INTAKE VS. DISCHARGE	0.134E+00	0.725E+00
02/10/76	2000	I5	38	3	0.709E+00	0.563E-01			
02/10/76	2000	D	38	3	0.719E+00	0.137E+00	INTAKE VS. DISCHARGE	0.488E-02	0.936E+00
02/11/76	0600	I5	0	3	0.101E+01	0.133E+00			
02/11/76	0600	D	0	3	0.105E+01	0.225E+00	INTAKE VS DISCHARGE	0.176E-01	0.887E+00
02/11/76	1215	I5	0	3	0.635E+00	0.436E-01			
02/11/76	1215	D	0	3	0.930E+00	0.154E+00	INTAKE VS. DISCHARGE	0.340E+01	0.141E+00
03/09/76	2030	I5	0	3	0.836E+00	0.191E+00			
03/09/76	2030	D	0	3	0.759E+00	0.160E+00	INTAKE VS. DISCHARGE	0.965E-01	0.761E+00
03/09/76	2030	I5	36	3	0.771E+00	0.196E+00			
03/09/76	2030	D	36	3	0.889E+00	0.114E+00	INTAKE VS. DISCHARGE	0.273E+00	0.628E+00
03/10/76	0505	I5	0	3	0.565E+00	0.723E-01			
03/10/76	0505	D	0	3	0.613E+00	0.149E+00	INTAKE VS. DISCHARGE	0.840E-01	0.775E+00
03/10/76	1218	I5	0	3	0.570E+00	0.302E-01			
03/10/76	1218	D	0	3	0.644E+00	0.101E+00	INTAKE VS. DISCHARGE	0.488E+00	0.525E+00
04/05/76	2101	I5	0	3	0.183E+01	0.125E+00			
04/05/76	2101	D	0	3	0.178E+01	0.182E+00	INTAKE VS. DISCHARGE	0.580E-01	0.808E+00
04/05/76	2101	I5	36	3	0.207E+01	0.623E-01			
04/05076	2101	D	36	3	0.192E+01	0.652E+00	INTAKE VS. DISCHARGE	0.520E-01	0.817E+00
04/06/76	0600	I5	0	3	0.218E+01	0.390E+00			
04/06/76	0600	D	0	3	0.162E+01	0.160E+00	INTAKE VS. DISCHARGE	0.174E+01	0.258E+00
04/06/76	1200	I5	0	3	0.188E+01	0.162E+00			
04/06/76	1200	D	0	3	0.182E+01	0.270E+00	INTAKE VS. DISCHARGE	0.363E-01	0.844E+00

TABLE 26. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
05/10/76	2120	I5 0	3	0.200E+01	0.503E-01			
05/10/76	2120	D 0	3	0.199E+01	0.119E+00	INTAKE VS. DISCHARGE	0.107E-01	0.910E+00
05/10/76	2120	I5 34	2	0.127E+01	0.812E+00			
05/10/76	2120	D 34	3	0.212E+01	0.395E+00	INTAKE VS. DISCHARGE	0.116E+01	0.362E+00
05/11/76/	0330	I5 0	3	0.273E+01	0.615E+00			
05/11/76	0330	D 0	3	0.258E+01	0.470E+00	INTAKE VS. DISCHARGE	0.359E-01	0.845E+00
05/11/76	1200	I5 0	3	0.275E+01	0.182E+00			
05/11/76	1200	D 0	3	0.353E+01	0.328E+00	INTAKE VS. DISCHARGE	0.432E+01	0.108E+00
06/14/76	2240	I5 0	3	0.709E+00	0.253E+00			
06/14/76	2240	D 0	3	0.614E+00	0.308E+00	INTAKE VS. DISCHARGE	0.576E-01	0.809E+00
06/14/76	2240	I5 33	3	0.319E+00	0.199E+00			
06/14/76	2240	D 33	3	0.847E+00	0.172E+00	INTAKE VS. DISCHARGE	0.404E+01	0.117E+00
06/15/76	0330	I5 0	3	0.370E+00	0.141E+00			
06/15/76	0330	D 0	3	0.426E+00	0.718E-01	INTAKE VS. DISCHARGE	0.124E+00	0.734E+00
06/15/76	1110	I5 0	3	0.587E+00	0.846E-01			
06/15/76	1110	D 0	3	0.600E+00	0.393E-01	INTAKE VS. DISCHARGE	0.175E-01	0.888E+00
07/12/76	2250	I5 0	3	0.148E+01	0.143E+00			
07/12/76	2250	D 0	3	0.897E+00	0.342E+00	INTAKE VS. DISCHARGE	0.249E+01	0.191E+00
07/12/76	2250	I5 37	3	0.114E+01	0.200E+00			
07/12/76	2250	D 37	3	0.117E+01	0.440E+00	INTAKE VS. DISCHARGE	0.385E-02	0.943E+00
07/13/76	I5 0355	0	2	0.802E+00	0.508E+00			
07/13/76	0355	D 0	3	0.919E+00	0.240E+00	INTAKE VS. DISCHARGE	0.564E-01	0.814E+00
07/13/76	1235	I5 0	3	0.121E+01	0.229E+00			
07/13/76	1235	D 0	3	0.533E+00	0.835E-01	INTAKE VS. DISCHARGE	0.761E+01	0.534E-01
08/09/76	2145	I5 0	3	0.689E+00	0.742E-01			
08/09/76	2145	D 0	3	0.788E+00	0.930E-01	INTAKE VS. DISCHARGE	0.683E+00	0.458E+00
08/09/76	2145	I5 36	3	0.744E+00	0.741E-01			
08/09/76	2145	D 36	3	0.469E+00	0.245E+00	INTAKE VS. DISCHARGE	0.116E+01	0.344E+00
08/10/76	0355	I5 0	3	0.826E+00	0.122E+00			
08/10/76	0355	D 0	3	0.575E+00	0.719E-01	INTAKE VS. DISCHARGE	0.313E+01	0.153E+00
08/10/76	1205	I5 0	3	0.121E+01	0.551E-01			
08/10/76	1205	D 0	3	0.736E+00	0.257E+00	INTAKE VS. DISCHARGE	0.327E+01	0.147E+00

TABLE 26. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
09/22/76	2145	I5 0	3	0.396E+00	0.137E+00			
09/22/76	2145	D 0	3	0.814E+00	0.281E+00	INTAKE VS. DISCHARGE	0.179E+01	0.253E+00
09/22/76	2145	I5 38	2	0.477E+00	0.565E-01			
09/22/76	2145	D 38	3	0.571E+00	0.712E-01	INTAKE VS. DISCHARGE	0.861E+00	0.424E+00
09/23/76	0610	I5 0	3	0.649E+00	0.140E+00			
09/23/76	0610	D 0	3	0.102E+01	0.140E+00	INTAKE VS. DISCHARGE	0.355E+01	0.134E+00
09/23/76	1145	I5 0	3	0.108E+01	0.115E-01			
09/23/76	1145	D 0	2	0.778E+00	0.722E+00	INTAKE VS. DISCHARGE	0.315E+00	0.613E+00
10/11/76	2040	I5 0	3	0.857E+00	0.101E+00			
10/11/76	2040	D 0	3	0.808E+00	0.748E-01	INTAKE VS. DISCHARGE	0.155E+00	0.707E+00
10/11/76	2040	I5 38	3	0.797E+00	0.410E+00			
10/11/76	2040	D 38	3	0.301E+00	0.182E+00	INTAKE VS. DISCHARGE	0.122E+01	0.332E+00
10/12/76	0630	I5 0	3	0.852E+00	0.149E+00			
10/12/76	0630	D 0	3	0.643E+00	0.117E+00	INTAKE VS. DISCHARGE	0.123E+01	0.330E+00
10/12/76	1220	I5 0	3	0.856E+00	0.654E-01			
10/12/76	1220	D 0	3	0.960E+00	0.927E-01	INTAKE VS. DISCHARGE	0.974E+00	0.381E+00
11/08/76	1900	I5 0	3	0.905E+00	0.668E-01			
11/08/76	1900	D 0	3	0.599E+00	0.180E+00	INTAKE VS. DISCHARGE	0.255E+01	0.187E+00
11/08/76	1900	I5 41	3	0.540E+00	0.149E+00			
11/08/76	1900	D 41	3	0.439E+00	0.130E+00	INTAKE VS. DISCHARGE	0.258E+00	0.637E+00
11/09/76	0810	I5 0	3	0.614E+00	0.100E+00			
11/09/76	0810	D 0	3	0.591E+00	0.128E+00	INTAKE VS. DISCHARGE	0.195E-01	0.882E+00
11/09/76	1310	I5 0	3	0.781E+00	0.972E-01			
11/09/76	1310	D 0	3	0.106E+01	0.138E+00	INTAKE VS. DISCHARGE	0.269E+01	0.178E+00
12/15/76	1920	I5 0	3	0.108E+01	0.623E-01			
12/15/76	1920	D 0	3	0.897E+00	0.199E+00	INTAKE VS. DISCHARGE	0.748E+00	0.438E+00
12/15/76	1920	I5 36	3	0.125E+01	0.100E+00			
12/15/76	1920	D 36	3	0.122E+01	0.184E+00	INTAKE VS. DISCHARGE	0.274E-01	0.862E+00
12/16/76	0720	I5 0	3	0.129E+01	0.611E-01			
12/16/76	0720	D 0	3	0.117E+01	0.111E+00	INTAKE VS. DISCHARGE	0.942E+00	0.389E+00
12/16/76	1315	I5 0	3	0.119E+01	0.291E-01			
12/16/76	1315	D 0	3	0.110E+01	0.118E+00	INTAKE VS. DISCHARGE	0.635E+00	0.473E+00

TABLE 27. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANLAYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/13/76	1945	I5 0	3	0.330E+01	0.328E+00			
01/13/76	1945	D 0	3	0.217E+01	0.109E+01	INTAKE VS. DISCHARGE	0.976E+00	0.381E+00
01/13/76	1945	I5 38	3	0.113E+01	0.732E+00			
01/13/76	1945	D 38	3	0.330E+01	0.139E+00	INTAKE VS. DISCHARGE	0.853E+01	0.457E-01
01/14/76	0630	I5 0	3	0.142E+00	0.120E+00			
01/14/76	0630	D 0	3	0.316E+01	0.152E+01	INTAKE VS. DISCHARGE	0.391E+01	0.121E+00
01/14/76	1245	I5 0	3	0.121E+01	0.101E+00			
01/14/76	1245	D 0	3	0.320E+01	0.459E+00	INTAKE VS. DISCHARGE	0.180E+02	0.158E-01
02/10/76	2000	I5 0	3	0.390E-01	0.390E-01			
02/10/76	2000	D 0	3	0.184E+00	0.130E+00	INTAKE VS. DISCHARGE	0.114E+01	0.347E+00
02/10/76	2000	I5 38	3	0.708E+00	0.529E+00			
02/10/76	2000	D 38	3	0.159E-01	0.823E-02	INTAKE VS. DISCHARGE	0.171E+01	0.262E+00
02/11/76	0600	I5 0	3	0.511E+00	0.150E+00			
02/11/76	0600	D 0	3	0.267E+00	0.136E+00	INTAKE VS DISCHARGE	0.145E+01	0.296E+00
02/11/76	1215	I5 0	3	0.113E+01	0.567E-01			
02/11/76	1215	D 0	3	0.735E+00	0.297E-01	INTAKE VS. DISCHARGE	0.388E+02	0.543E-02
03/09/76	2030	I5 0	3	0.184E+00	0.261E-01			
03/09/76	2030	D 0	3	0.248E+00	0.149E+00	INTAKE VS. DISCHARGE	0.174E+00	0.693E+00
03/09/76	2030	I5 36	3	0.630E+00	0.285E+00			
03/09/76	2030	D 36	3	0.102E+01	0.546E+00	INTAKE VS. DISCHARGE	0.400E+00	0.563E+00
03/10/76	0505	I5 0	3	0.971E+00	0.150E+00			
03/10/76	0505	D 0	3	0.236E+00	0.221E+00	INTAKE VS. DISCHARGE	0.755E+01	0.540E-01
03/10/76	1218	I5 0	3	0.419E+00	0.263E+00			
03/10/76	1218	D 0	3	0.394E+00	0.104E+00	INTAKE VS. DISCHARGE	0.788E-02	0.922E+00
04/05/76	2101	I5 0	3	0.776E+00	0.228E+00			
04/05/76	2101	D 0	3	0.814E+00	0.340E+00	INTAKE VS. DISCHARGE	0.877E-02	0.918E+00
04/05/76	2101	I5 36	3	0.339E+01	0.390E+00			
04/05076	2101	D 36	3	0.332E+01	0.289E+00	INTAKE VS. DISCHARGE	0.188E-01	0.884E+00
04/06/76	0600	I5 0	3	0.630E+00	0.630E+00			
04/06/76	0600	D 0	3	0.991E+00	0.703E-01	INTAKE VS. DISCHARGE	0.324E+00	0.600E+00
04/06/76	1200	I5 0	3	0.139E+01	0.714E+00			
04/06/76	1200	D 0	3	0.419E+00	0.217E-01	INTAKE VS. DISCHARGE	0.185E+01	0.247E+00

TABLE 27. CONT.

DATE	TIME	INC.		SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
05/10/76	2120	I5	0	3	0.266E+00	0.243E+00			
05/10/76	2120	D	0	3	0.240E+00	0.124E+00	INTAKE VS. DISCHARGE	0.928E-02	0.916E+00
05/10/76	2120	I5	34	2	0.403E+01	0.220E+00			
05/10/76	2120	D	34	3	0.261E+01	0.332E+00	INTAKE VS. DISCHARGE	0.951E+01	0.553E-01
05/11/76/	0330	I5	0	3	0.0	0.0			
05/11/76	0330	D	0	3	0.505E+00	0.277E+00	INTAKE VS. DISCHARGE	0.333E+01	0.144E+00
05/11/76	1200	I5	0	3	0.450E+01	0.542E+00			
05/11/76	1200	D	0	3	0.127E+01	0.127E+01	INTAKE VS. DISCHARGE	0.552E+01	0.808E-01
06/14/76	2240	I5	0	3	0.431E+00	0.163E+00			
06/14/76	2240	D	0	3	0.769E+00	0.395E+00	INTAKE VS. DISCHARGE	0.624E+00	0.477E+00
06/14/76	2240	I5	33	3	0.857E-01	0.857E-01			
06/14/76	2240	D	33	3	0.272E+00	0.272E+00	INTAKE VS. DISCHARGE	0.428E+00	0.550E+00
06/15/76	0330	I5	0	3	0.304E+00	0.304E+00			
06/15/76	0330	D	0	3	0.297E+00	0.161E+00	INTAKE VS. DISCHARGE	0.414E-03	0.974E+00
06/15/76	1110	I5	0	3	0.163E+00	0.130E+00			
06/15/76	1110	D	0	3	0.137E+00	0.769E-01	INTAKE VS. DISCHARGE	0.289E-01	0.859E+00
07/12/76	2250	I5	0	3	0.514E+01	0.520E+00			
07/12/76	2250	D	0	3	0.478E+01	0.108E+01	INTAKE VS. DISCHARGE	0.919E-01	0.766E+00
07/12/76	2250	I5	37	3	0.343E+01	0.384E+00			
07/12/76	2250	D	37	3	0.434E+01	0.114E+01	INTAKE VS. DISCHARGE	0.570E+00	0.495E+00
07/13/76I5	0355		0	2	0.228E+01	0.610E+00			
07/13/76	0355	D	0	3	0.213E+01	0.960E-01	INTAKE VS. DISCHARGE	0.106E+00	0.756E+00
07/13/76	1235	I5	0	3	0.194E+01	0.809E-01			
07/13/76	1235	D	0	3	0.148E+01	0.213E+00	INTAKE VS. DISCHARGE	0.396E+01	0.119E+00
08/09/76	2145	I5	0	3	0.538E+00	0.277E-01			
08/09/76	2145	D	0	3	0.533E+00	0.944E-01	INTAKE VS. DISCHARGE	0.225E-02	0.954E+00
08/09/76	2145	I5	36	3	0.439E+00	0.437E-01			
08/09/76	2145	D	36	3	0.550E+00	0.748E-01	INTAKE VS. DISCHARGE	0.163E+01	0.272E+00
08/10/76	0355	I5	0	3	0.405E+00	0.203E+00			
08/10/76	0355	D	0	3	0.988E+00	0.835E-01	INTAKE VS. DISCHARGE	0.705E+01	0.591E-01
08/10/76	1205	I5	0	3	0.600E+00	0.188E+00			
08/10/76	1205	D	0	3	0.951E+00	0.238E+00	INTAKE VS. DISCHARGE	0.134E+01	0.313E+00

TABLE 27. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
09/22/76	2145	I5 0	3	0.880E-01	0.880E-01			
09/22/76	2145	D 0	3	0.184E+00	0.778E-01	INTAKE VS. DISCHARGE	0.670E+00	0.462E+00
09/22/76	2145	I5 38	2	0.440E+00	0.111E+00			
09/22/76	2145	D 38	3	0.574E+00	0.258E+00	INTAKE VS. DISCHARGE	0.151E+00	0.716E+00
09/23/76	0610	I5 0	3	0.165E+01	0.801E-01			
09/23/76	0610	D 0	3	0.209E+01	0.407E+00	INTAKE VS. DISCHARGE	0.111E+01	0.354E+00
09/23/76	1145	I5 0	3	0.187E+01	0.173E+00			
09/23/76	1145	D 0	2	0.226E+01	0.790E+00	INTAKE VS. DISCHARGE	0.377E+00	0.582E+00
10/11/76	2040	I5 0	3	0.870E-02	0.870E-02			
10/11/76	2040	D 0	3	0.188E+00	0.101E+00	INTAKE VS. DISCHARGE	0.315E+01	0.152E+00
10/11/76	2040	I5 38	3	0.245E-01	0.245E-01			
10/11/76	2040	D 38	3	0.503E-01	0.503E-01	INTAKE VS. DISCHARGE	0.213E+00	0.665E+00
10/12/76	0630	I5 0	3	0.890E-02	0.890E-02			
10/12/76	0630	D 0	3	0.333E-01	0.333E-01	INTAKE VS. DISCHARGE	0.502E+00	0.520E+00
10/12/76	1220	I5 0	3	0.348E+00	0.174E+00			
10/12/76	1220	D 0	3	0.274E+00	0.870E-01	INTAKE VS. DISCHARGE	0.143E+00	0.718E+00
11/08/76	1900	I5 0	3	0.714E+00	0.810E-01			
11/08/76	1900	D 0	3	0.530E+00	0.863E-01	INTAKE VS. DISCHARGE	0.242E+01	0.196E+00
11/08/76	1900	I5 41	3	0.278E+00	0.114E+00			
11/08/76	1900	D 41	3	0.825E+00	0.874E-01	INTAKE VS. DISCHARGE	0.145E+02	0.215E-01
11/09/76	0810	I5 0	3	0.215E+00	0.173E+00			
11/09/76	0810	D 0	3	0.304E+00	0.123E+00	INTAKE VS. DISCHARGE	0.178E+00	0.690E+00
11/09/76	1310	I5 0	3	0.703E+00	0.141E+00			
11/09/76	1310	D 0	3	0.182E+00	0.667E-01	INTAKE VS. DISCHARGE	0.112E+02	0.314E-01
12/15/76	1920	I5 0	3	0.220E+00	0.552E-01			
12/15/76	1920	D 0	3	0.682E+00	0.237E+00	INTAKE VS. DISCHARGE	0.360E+01	0.132E+00
12/15/76	1920	I5 36	3	0.531E+00	0.374E+00			
12/15/76	1920	D 36	3	0.129E+00	0.659E-01	INTAKE VS. DISCHARGE	0.112E+01	0.352E+00
12/16/76	0720	I5 0	3	0.883E-02	0.883E-02			
12/16/76	0720	D 0	3	0.295E+00	0.267E+00	INTAKE VS. DISCHARGE	0.115E+01	0.346E+00
12/16/76	1315	I5 0	3	0.0	0.0			
12/16/76	1315	D 0	3	0.236E+00	0.121E+00	INTAKE VS. DISCHARGE	0.379E+01	0.125E+00

TABLE 28. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
01/13/76	1945	I5 0	3	0.105E+01	0.394E-01			
01/13/76	1945	D 0	3	0.674E+00	0.345E+00	INTAKE VS. DISCHARGE	0.119E+01	0.338E+00
01/13/76	1945	I5 38	3	0.251E+00	0.147E+00			
01/13/76	1945	D 38	3	0.812E+00	0.449E-01	INTAKE VS. DISCHARGE	0.133E+02	0.244E-01
01/14/76	0630	I5 0	3	0.271E-01	0.234E-01			
01/14/76	0630	D 0	3	0.135E+01	0.724E+00	INTAKE VS. DISCHARGE	0.335E+01	0.143E+00
01/14/76	1245	I5 0	3	0.332E+00	0.846E-01			
01/14/76	1245	D 0	3	0.896E+00	0.159E+00	INTAKE VS. DISCHARGE	0.986E+01	0.374E-01
02/10/76	2000	I5 0	3	0.147E-01	0.147E-01			
02/10/76	2000	D 0	3	0.729E-01	0.531E-01	INTAKE VS. DISCHARGE	0.112E+01	0.351E+00
02/10/76	2000	I5 38	3	0.451E+00	0.380E+00			
02/10/76	2000	D 38	3	0.629E-02	0.324E-02	INTAKE VS. DISCHARGE	0.137E+01	0.308E+00
02/11/76	0600	I5 0	3	0.256E+00	0.837E-01			
02/11/76	0600	D 0	3	0.134E+00	0.717E-01	INTAKE VS DISCHARGE	0.122E+01	0.332E+00
02/11/76	1215	I5 0	3	0.642E+00	0.377E-01			
02/11/76	1215	D 0	3	0.361E+00	0.175E-01	INTAKE VS. DISCHARGE	0.460E+02	0.436E-02
03/09/76	2030	I5 0	3	0.732E-01	0.111E-01			
03/09/76	2030	D 0	3	0.102E+00	0.589E-01	INTAKE VS. DISCHARGE	0.233E+00	0.652E+00
03/09/76	2030	I5 36	3	0.289E+00	0.144E+00			
03/09/76	2030	D 36	3	0.525E+00	0.300E+00	INTAKE VS. DISCHARGE	0.505E+00	0.519E+00
03/10/76	0505	I5 0	3	0.554E+00	0.115E+00			
03/10/76	0505	D 0	3	0.123E+00	0.117E+00	INTAKE VS. DISCHARGE	0.690E+01	0.607E-01
03/10/76	1218	I5 0	3	0.233E+00	0.162E+00			
03/10/76	1218	D 0	3	0.188E+00	0.578E-01	INTAKE VS. DISCHARGE	0.697E-01	0.793E+00
04/05/76	2101	I5 0	3	0.126E+00	0.389E-01			
04/05/76	2101	D 0	3	0.144E+00	0.629E-01	INTAKE VS. DISCHARGE	0.575E-01	0.809E+00
04/05/76	2101	I5 36	3	0.767E+00	0.100E+00			
04/05076	2101	D 36	3	0.881E+00	0.156E+00	INTAKE VS. DISCHARGE	0.376E+00	0.574E+00
04/06/76	0600	I5 0	3	0.139E+00	0.139E+00			
04/06/76	0600	D 0	3	0.195E+00	0.172E-01	INTAKE VS. DISCHARGE	0.160E+00	0.704E+00
04/06/76	1200	I5 0	3	0.324E+00	0.171E+00			
04/06/76	1200	D 0	3	0.834E-01	0.853E-02	INTAKE VS. DISCHARGE	0.199E+01	0.232E+00

TABLE 20. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
05/10/76	2120	I5 0	3	0.366E-01	0.337E-01			
05/10/76	2120	D 0	3	0.353E-01	0.181E-01	INTAKE VS. DISCHARGE	0.122E-02	0.963E+00
05/10/76	2120	I5 34	2	0.896E+00	0.165E+00			
05/10/76	2120	D 34	3	0.498E+00	0.943E-01	INTAKE VS. DISCHARGE	0.529E+01	0.107E+00
05/11/76/	0330	I5 0	3	0.0	0.0			
05/11/76	0330	D 0	3	0.645E-01	0.356E-01	INTAKE VS. DISCHARGE	0.328E+01	0.146E+00
05/11/76	1200	I5 0	3	0.609E+00	0.447E-01			
05/11/76	1200	D 0	3	0.135E+00	0.135E+00	INTAKE VS. DISCHARGE	0.112E+02	0.314E-01
06/14/76	2240	I5 0	3	0.148E+00	0.573E-01			
06/14/76	2240	D 0	3	0.425E+00	0.216E+00	INTAKE VS. DISCHARGE	0.154E+01	0.283E+00
06/14/76	2240	I5 33	3	0.343E-01	0.343E-01			
06/14/76	2240	D 33	3	0.343E+00	0.343E+00	INTAKE VS. DISCHARGE	0.802E+00	0.424E+00
06/15/76	0330	I5 0	3	0.113E+00	0.113E+00			
06/15/76	0330	D 0	3	0.112E+00	0.646E-01	INTAKE VS. DISCHARGE	0.422E-05	0.985E+00
06/15/76	1110	I5 0	3	0.519E-01	0.434E-01			
06/15/76	1110	D 0	3	0.434E-01	0.236E-01	INTAKE VS. DISCHARGE	0.299E-01	0.857E+00
07/12/76	2250	I5 0	3	0.431E+00	0.539E-01			
07/12/76	2250	D 0	3	0.415E+00	0.133E+00	INTAKE VS. DISCHARGE	0.119E-01	0.906E+00
07/12/76	2250	I5 37	3	0.297E+00	0.459E-01			
07/12/76	2250	D 37	3	0.443E+00	0.129E+00	INTAKE VS. DISCHARGE	0.114E+01	0.347E+00
07/13/76I5	0355	0	2	0.227E+00	0.685E-01			
07/13/76	0355	D 0	3	0.205E+00	0.223E-01	INTAKE VS. DISCHARGE	0.143E+00	0.722E+00
07/13/76	1235	I5 0	3	0.264E+00	0.636E-02			
07/13/76	1235	D 0	3	0.213E+00	0.395E-01	INTAKE VS. DISCHARGE	0.165E+01	0.270E+00
08/09/76	2145	I5 0	3	0.167E+00	0.584E-02			
08/09/76	2145	D 0	3	0.183E+00	0.353E-01	INTAKE VS. DISCHARGE	0.208E+00	0.668E+00
08/09/76	2145	I5 36	3	0.144E+00	0.114E-01			
08/09/76	2145	D 36	3	0.256E+00	0.450E-01	INTAKE VS. DISCHARGE	0.583E+01	0.754E-01
08/10/76	0355	I5 0	3	0.920E-01	0.464E-01			
08/10/76	0355	D 0	3	0.252E+00	0.265E-01	INTAKE VS. DISCHARGE	0.895E+01	0.428E-01
08/10/76	1205	I5 0	3	0.154E+00	0.561E-01			
08/10/76	1205	D 0	3	0.329E+00	0.933E-01	INTAKE VS. DISCHARGE	0.259E+01	0.184E+00

TABLE 28. CONT.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
09/22/76	2145	I5 0	3	0.257E-01	0.257E-01			
09/22/76	2145	D 0	3	0.521E-01	0.219E-01	INTAKE VS. DISCHARGE	0.612E+00	0.480E+00
09/22/76	2145	I5 38	2	0.171E+00	0.440E-01			
09/22/76	2145	D 38	3	0.247E+00	0.114E+00	INTAKE VS. DISCHARGE	0.256E+00	0.645E+00
09/23/76	0610	I5 0	3	0.355E+00	0.254E-01			
09/23/76	0610	D 0	3	0.508E+00	0.119E+00	INTAKE VS. DISCHARGE	0.159E+01	0.277E+00
09/23/76	1145	I5 0	3	0.304E+00	0.288E-01			
09/23/76	1145	D 0	2	0.433E+00	0.191E+00	INTAKE VS. DISCHARGE	0.773E+00	0.446E+00
10/11/76	2040	I5 0	3	0.254E-02	0.254E-02			
10/11/76	2040	D 0	3	0.671E-01	0.355E-01	INTAKE VS. DISCHARGE	0.328E+01	0.146E+00
10/11/76	2040	I5 38	3	0.903E-02	0.903E-02			
10/11/76	2040	D 38	3	0.255E-01	0.255E-01	INTAKE VS. DISCHARGE	0.370E+00	0.577E+00
10/12/76	0630	I5 0	3	0.259E-02	0.259E-02			
10/12/76	0630	D 0	3	0.927E-02	0.927E-02	INTAKE VS. DISCHARGE	0.482E+00	0.528E+00
10/12/76	1220	I5 0	3	0.907E-01	0.456E-01			
10/12/76	1220	D 0	3	0.694E-01	0.206E-01	INTAKE VS. DISCHARGE	0.180E+00	0.689E+00
11/08/76	1900	I5 0	3	0.214E+00	0.228E-01			
11/08/76	1900	D 0	3	0.166E+00	0.331E-01	INTAKE VS. DISCHARGE	0.144E+01	0.297E+00
11/08/76	1900	I5 41	3	0.912E-01	0.363E-01			
11/08/76	1900	D 41	3	0.322E+00	0.472E-01	INTAKE VS. DISCHARGE	0.150E+02	0.206E-01
11/09/76	0810	I5 0	3	0.729E-01	0.601E-01			
11/09/76	0810	D 0	3	0.111E+00	0.464E-01	INTAKE VS. DISCHARGE	0.248E+00	0.643E+00
11/09/76	1310	I5 0	3	0.231E+00	0.468E-01			
11/09/76	1310	D 0	3	0.447E-01	0.159E-01	INTAKE VS. DISCHARGE	0.141E+02	0.224E-01
12/15/76	1920	I5 0	3	0.466E-01	0.123E-01			
12/15/76	1920	D 0	3	0.174E+00	0.739E-01	INTAKE VS. DISCHARGE	0.290E+01	0.165E+00
12/15/76	1920	I5 36	3	0.116E+00	0.861E-01			
12/15/76	1920	D 36	3	0.263E-01	0.134E-01	INTAKE VS. DISCHARGE	0.105E+01	0.364E+00
12/16/76	0720	I5 0	3	0.185E-02	0.185E-02			
12/16/76	0720	D 0	3	0.614E-01	0.559E-01	INTAKE VS. DISCHARGE	0.113E+01	0.349E+00
12/16/76	1315	I5 0	3	0.0	0.0			
12/16/76	1315	D 0	3	0.414E-01	0.212E-01	INTAKE VS. DISCHARGE	0.381E+01	0.125E+00

different at the 0.05 level of significance between intake and discharge were: 1) 11 February 1976 at 1215 EST with 0 hours incubation the intake had lower concentrations than the discharge; 2) 9 August 1976 at 2145 EST with 0 hours incubation the intake had higher concentrations than the discharge; 3) 9 August 1976 at 2145 EST with 36 hours incubation, the intake had higher concentrations than the discharge; 4) 10 August 1976 at 0355 EST with 0 hours incubation, the intake had higher concentrations than the discharge; 5) 10 August 1976 at 1205 EST with 0 hours incubation, the intake had higher concentrations than the discharge; and 6) 9 November 1976 at 1310 EST with 0 hours incubation, the intake had lower concentrations than the discharge. Differences between intake and discharge concentrations of chlorophyll *b* occurred on the following days: 1) 8 November 1976 at 1900 EST with 0 hours incubation, the intake had lower concentrations than the discharge; and 2) 15 December 1976 at 1920 EST with 0 hours incubation the intake concentrations were lower than those of the discharge. Chlorophyll *c* concentrations at the intake were different from those at the discharge on 13 January 1976 at 1945 EST with 38 hours incubation, the intake had higher concentrations than the discharge. Phaeophytin *a* differences between intake and discharge concentrations (0.05 level of significance) were noted for the following days: 1) 13 January 1976 at 1945 EST with 38 hours incubation, the intake had a lower concentration than the discharge; 2) 14 January 1976 at 1245 EST with 0 hours incubation the intake had a lower concentration than the discharge; 3) 11 February 1976 at 1215 EST with 0 hours incubation, the intake had a higher concentration than the discharge; 4) 8 November 1976 at 1900 EST with 41 hours incubation, the intake had a lower concentration than

the discharge; and 5) 9 November 1976 at 1310 EST with 0 hours incubation, the intake had a higher concentration than the discharge. For the ratio of phaeophytin *a* to chlorophyll *a* the following significant differences (0.05 level of significance) were noted: 1) 13 January 1976 at 1945 EST with 38 hours incubation, the discharge ratio was greater than that of the intake; 2) 14 January 1976 at 1245 EST with 0 hours incubation the discharge ratio was largest; 3) 11 February 1976 at 1215 EST with 0 hours incubation the intake ratio was the largest; 4) 11 May 1976 at 1200 EST with 0 hours incubation, the intake had a higher ratio than the discharge; 5) 10 August 1976 at 0355 EST with 0 hours incubation, the intake had a lower ratio than the discharge; 6) 8 November 1976 at 1900 EST with 41 hours incubation, the intake had a lower ratio than the discharge; and 7) 9 November 1976 at 1310 EST with 0 hours incubation, the intake had a higher ratio than the discharge. Thus for 21 of a possible 240 comparisons a significant difference between intake and discharge was observed. Twelve of these showed inhibition of the phytoplankton and nine enhancement of the phytoplankton. Five occurrences were in January, three in February, one in May, five in August, six in November, and one in December.

Relative to the intake, the decrease in chlorophyll *c* at the discharge on 13 January at 1945 EST coincided with a decrease in the numbers of diatoms; the increase in the phaeophytin *a* and the phaeophytin *a*/chlorophyll *a* ratio on 13 January at 1945 EST at the discharge coincided with a small decrease in total phytoplankton numbers, an increase in flagellates and a decrease in diatoms; the increase in phaeophytin *a* and increase in the ratio coincided with decreased concentrations of total phytoplankton, diatoms, and coccoid blue-green algae. On 11 February at 1215 EST, a decrease in phaeophytin *a*

and the ratio and an increase in chlorophyll *a* coincided with a decrease in the number of diatoms and coccoid blue-green algae and an increase in coccoid green algae and flagellates at the discharge relative to the intake. A decrease in the phaeophytin *a*/chlorophyll *a* ratio at the discharge relative to the intake on 11 May at 1200 EST was coincident with a decrease in the total number of phytoplankton at the discharge. A decrease in chlorophyll *a* at the discharge on 9 August at 2145 coincided with a similar decrease in total phytoplankton numbers. On 10 August at 0355, decreases in chlorophyll *a* and an increase in the ratio occurring between the intake and discharge coincided with increases in total phytoplankton, diatoms, and coccoid green algae and decreases in coccoid blue-green algae and flagellates. A decrease in chlorophyll *a* between the intake and discharge on 10 August at 1205 EST coincided with increases in total phytoplankton, diatoms, and coccoid green algae and decreases in flagellate numbers. A decrease in phaeophytin *a* and the phaeophytin *a*/chlorophyll *a* ratio and an increase in chlorophyll *a* on 9 November at 1310 EST corresponded to increased numbers at the discharge of total phytoplankton primarily as diatoms and coccoid green algae. Increased numbers at the discharge of total phytoplankton, diatoms, flagellates, coccoid green algae, and coccoid blue-green algae corresponded to an increase in chlorophyll *b*, phaeophytin *a*, and the ratio. On 15 December at 1920 an increase in chlorophyll *b* at the discharge coincided with decreases of coccoid green algae, flagellates, diatoms, coccoid blue-green algae, and total phytoplankton numbers. The above discussion illustrates how apparent changes in viability reflected by chlorophyll *a* and phaeophytin *a* measurements can be influenced by "short-term" changes in the phytoplankton community being sampled. The

phytoplankton were so heterogenous that sampling of different populations could account for all the significant changes in viability observed through chlorophyll and phaeophytin *a* measurements. This variation was similar to that found in the short-term variation discussed in the previous section. There is no way to ascertain whether differences noted were a result of natural community changes or plant impact on the phytoplankton. Therefore, the worst possible case will be assumed; namely that the changes noted were all related to operation of the Donald C. Cook Nuclear Plant. Using this assumption, 21 changes in chlorophyll *a*, phaeophytin *a*, and the phaeophytin *a*/chlorophyll *a* ratio occurred in 1976. With 240 comparisons being made, a possible measureable plant impact occurred a maximum of 8.75% of the time with 5% being inhibition and 3.75% being enhancement of the phytoplankton. These results were slightly higher than those for 1975 which were 3.6% and 1.8% respectively. This excludes periods of chlorination when some damage may possibly occur. A discussion of chlorination impact will appear in the report on the 1977 data.

The results presented by us are somewhat similar to those reported by others for thermal impact studies on the Great Lakes. For the Palisades nuclear power plant, Benda, Gulvas and Neal (1975) and Benda and Gulvas (1976) reported 32.7% loss in primary productivity for heated discharge waters and a 17.9% loss for a non-heated discharge. Thus approximately one-half of the decrease in primary productivity measured using the ^{14}C method was due to mechanical stress. The Palisades plant is located 26 km north of Benton Harbor, Michigan.

For the Zion nuclear plant located 5 km south of the Wisconsin-Illinois

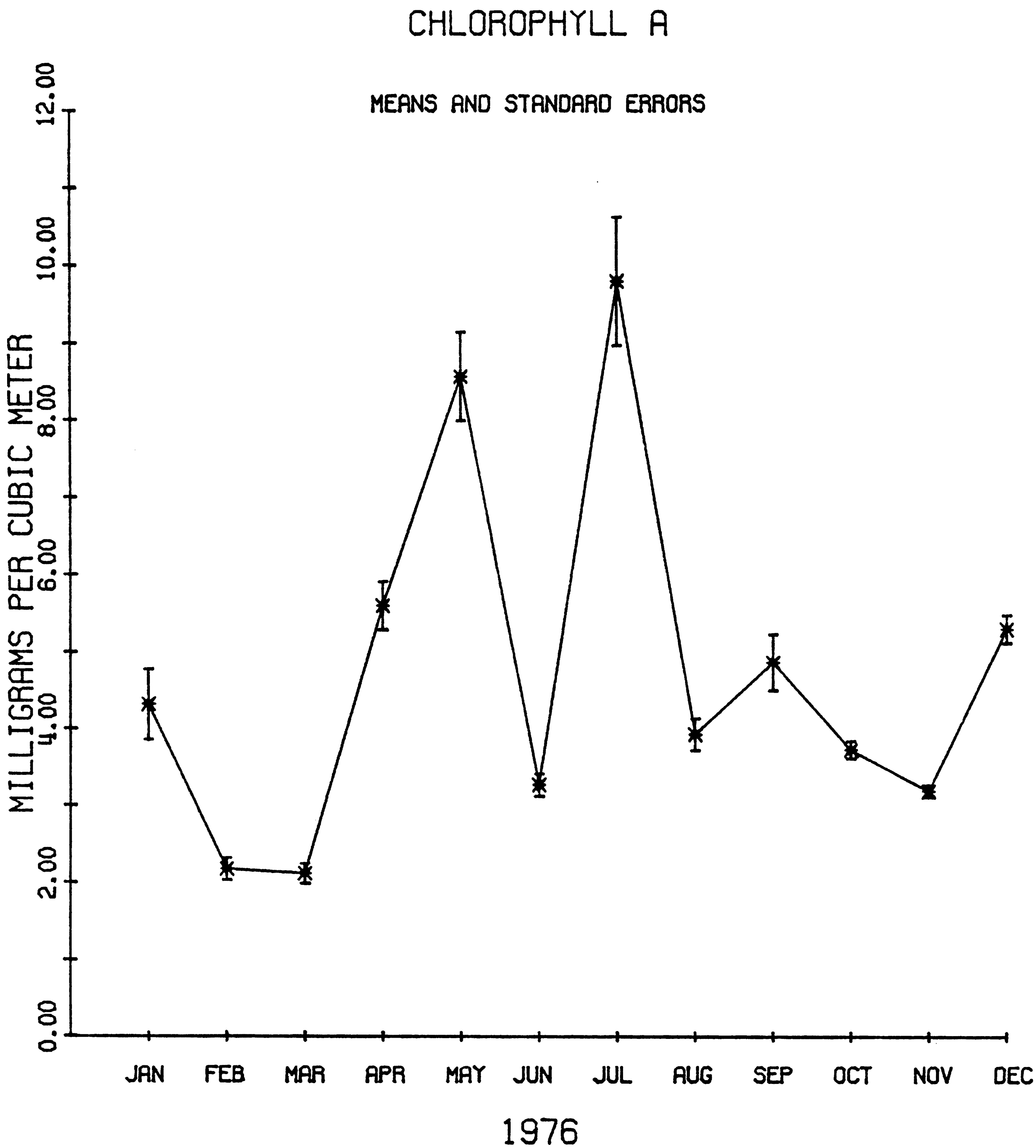

FIG. 20. Variation of chlorophyll *a* concentrations during 1976.

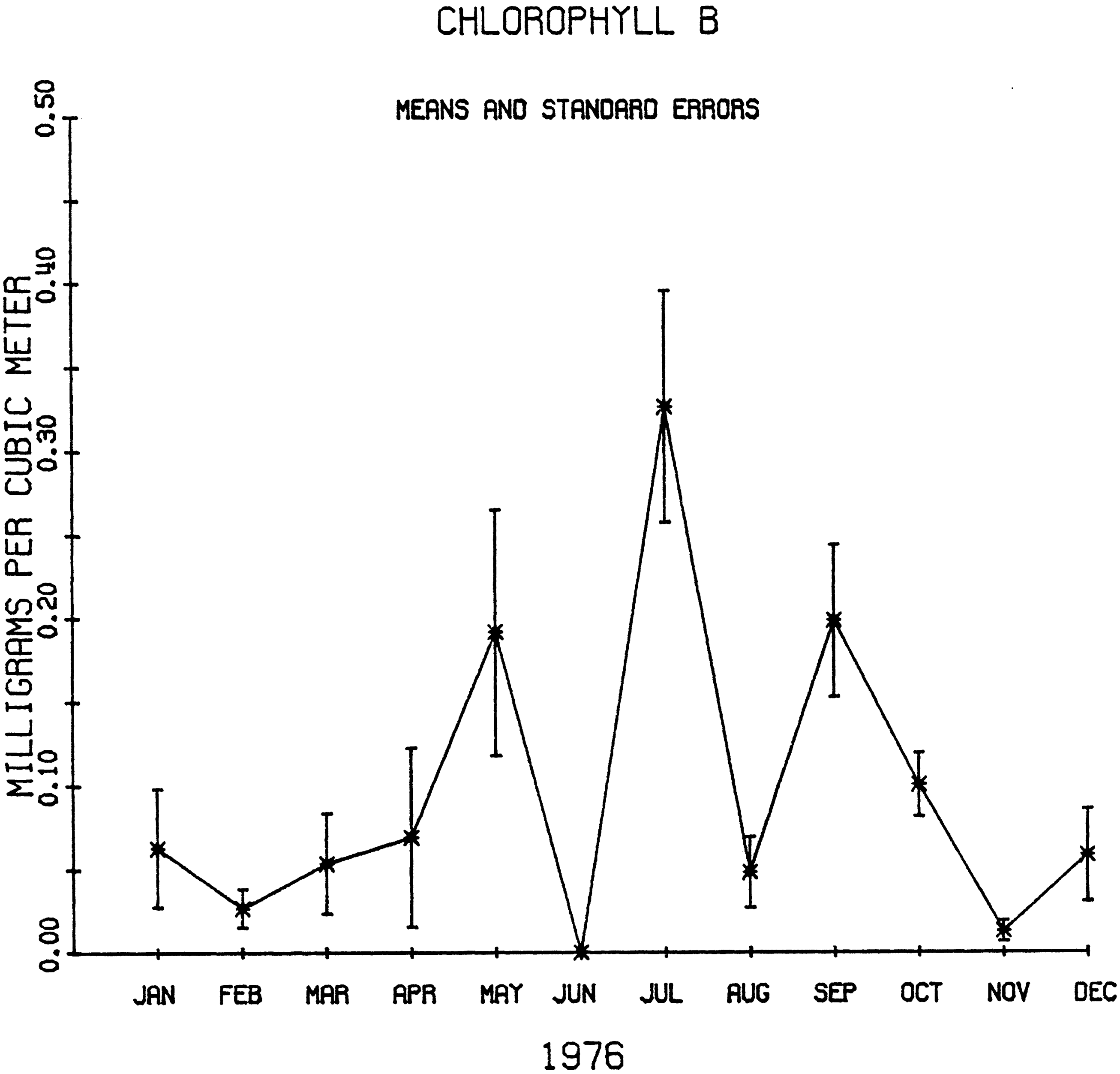

FIG. 21. Variation of chlorophyll *b* concentrations during 1976.

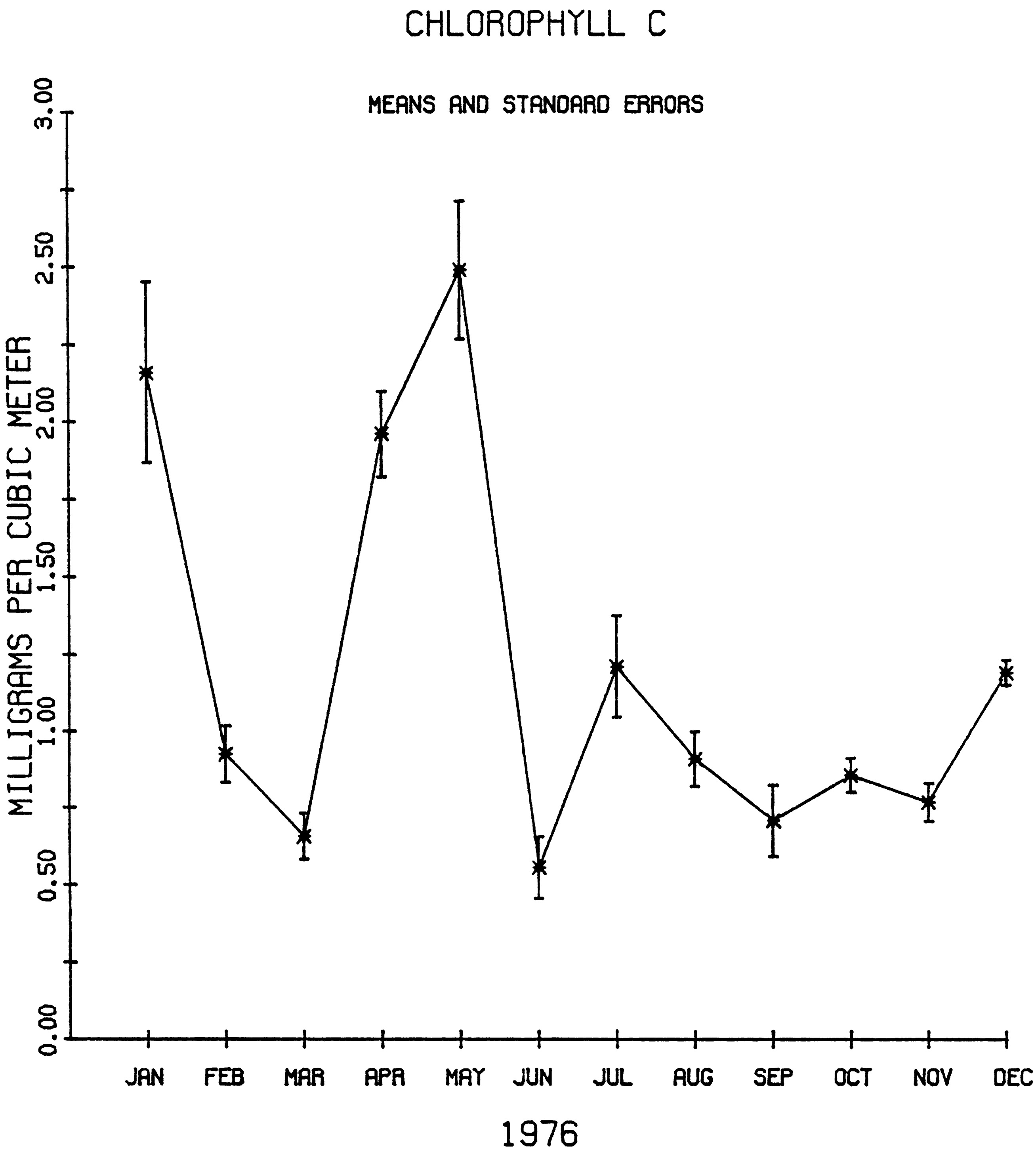

FIG. 22. Variation of chlorophyll *c* concentrations during 1976.

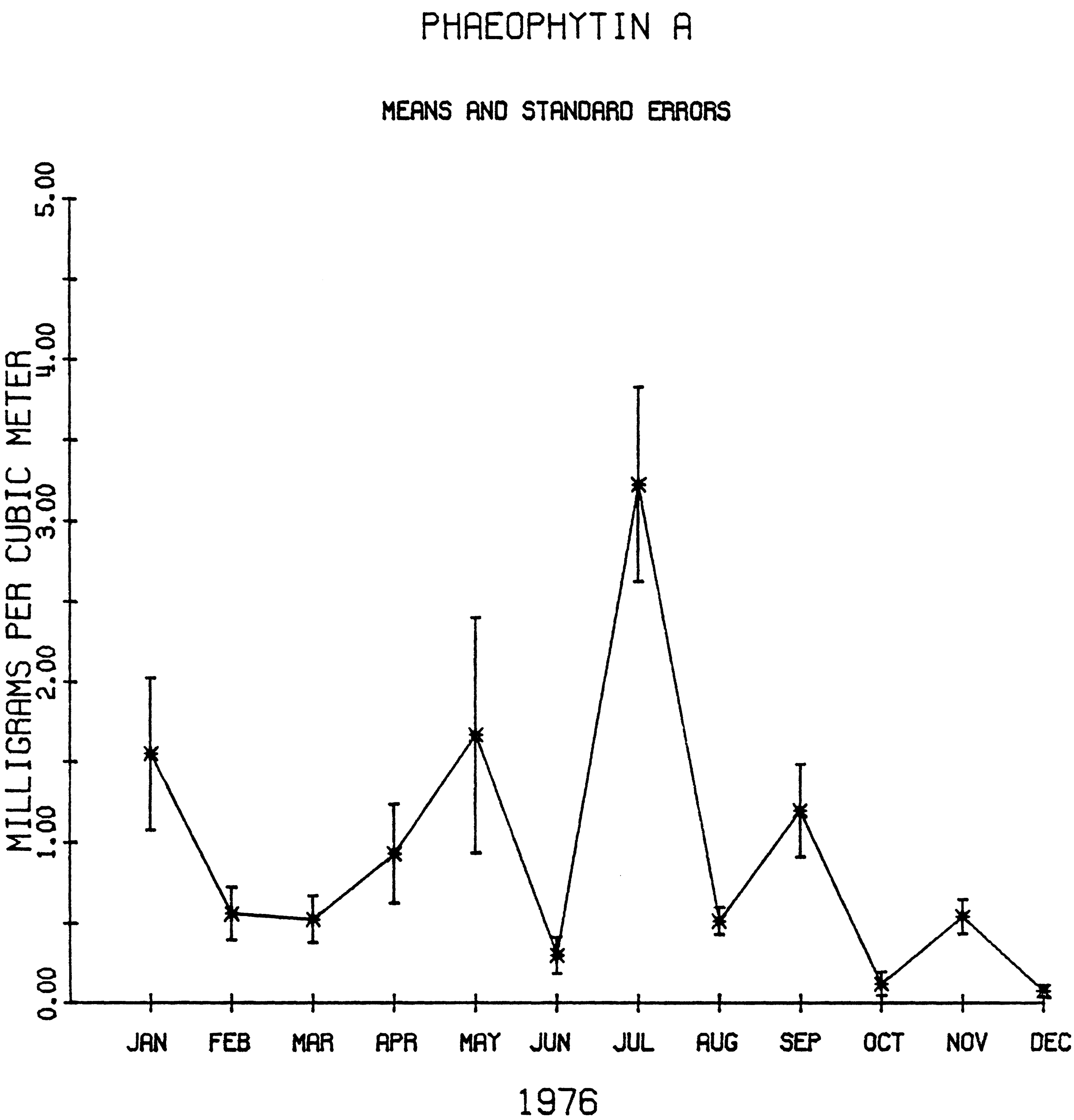

FIG. 23. Variation of phaeophytin *a* concentrations during 1976.

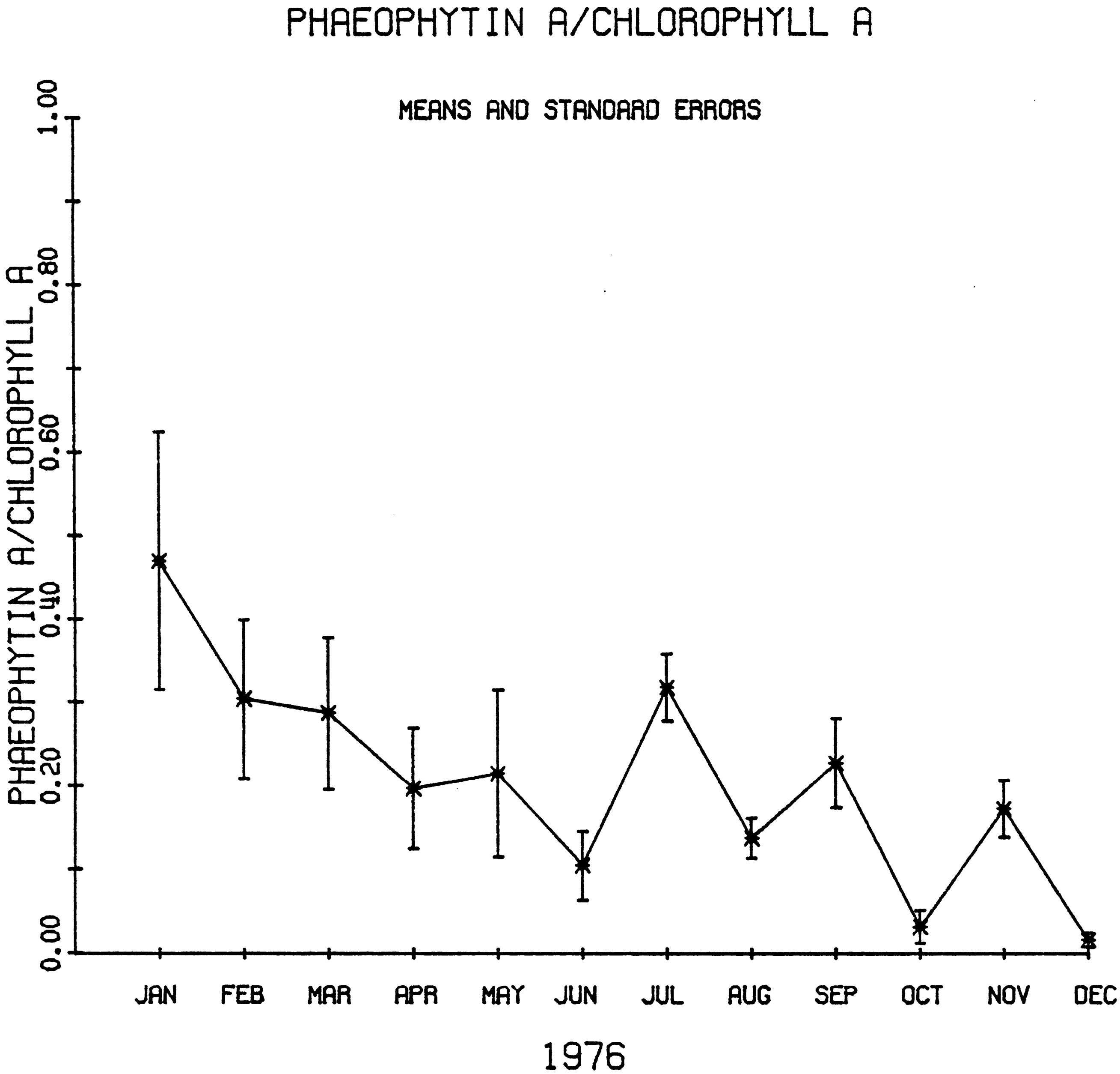

FIG. 24. Variation of the phaeophytin *a*/chlorophyll *a* ratio during 1976.

state line, Yaguchi (1977) found growth rates of phytoplankton in the plant, warm-water plume in Lake Michigan were greater than those at central stations only during upwelling.

Wiersma et al. (1974) found little or no effect of heated discharge water on primary productivity for phytoplankton populations impacted by a fossil fuel power plant located at the confluence on the Fox River with Green Bay.

Fenton et al. (1971) found that addition of heat to Lake Erie at Nine Mile Point had no significant affect on primary production.

Beeton and Barker (1974) found that temperature increases of 2-7°C caused no changes in chlorophyll levels. However, entrainment was shown to increase primary productivity as much as 64%.

Monthly Variation of the Chlorophylls and Phaeophytin a

Figures 20 through 24 illustrate the variation of chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, phaeophytin *a*, and the phaeophytin *a*/chlorophyll *a* ratio during 1976 at the intake forebay of the Donald C. Cook Nuclear Plant. Chlorophylls *a* and *c* were high during January, April, May, July, and December. Chlorophyll *b* was high during May, July, and September. Phaeophytin *a* exhibited peaks in its concentration during May, July, and perhaps September. The phaeophytin *a*/chlorophyll *a* ratio was highest in January and steadily decreased through June. The ratio was erratic during July through September, but it progressively decreased.

Peak concentrations of the chlorophylls and phaeophytin *a* during April and May were associated with the normal spring phytoplankton bloom. Peaks during January and December were representative of the normal winter phytoplankton

bloom. Peaks in July and September were a direct result of upwelling events occurring during those months at or before the time of sample collection. The 1976 results were somewhat similar to those of 1975. During 1975, the spring bloom commenced in April and continued in June. In 1975, upwellings were noted in September and October.

Variation of chlorophylls, phaeophytin *a*, and the phaeophytin *a*/chlorophyll *a* ratio can be further interpreted in terms of nutrient supply. Referring to Table 3, orthophosphate and dissolved silica concentrations were high January through March. With the beginning of the spring bloom of pennate diatoms (Figure 8) in April, orthophosphate decreased dramatically and dissolved silica decreased. At the peak of the spring centric diatom (Figure 7), filamentous blue-green algae (Figure 3), filamentous green algae (Figure 5), flagellate (Figure 6), and total algae (Figure 11) blooms in May, dissolved silica concentrations greatly decreased and continued to decrease through June. May storms during sampling elevated orthophosphate concentrations. Upwelling in July increased both orthophosphate and dissolved silica concentrations resulting in high cocoid green algae (Figure 4), centric diatom (Figure 7), pennate diatom (Figure 9), other algae (Figure 10), and total phytoplankton (Figure 11) concentrations. These concentrations remained relatively high through November due to upwellings in July, August, and September and due to storms in October and November which served to return the lake to isothermal conditions. These high concentrations maintained peak concentrations of coccoid blue-gree algae (Figure 2), coccoid green algae (Figure 4), and other algae (Figure 10). In December commencement of the winter bloom of pennate diatoms (Figure 8) lowered orthophosphate concentration and continued the decrease in dissolved silica.

CONCLUSION

Phytoplankton entrained by the Donald C. Cook Nuclear Plant during 1976 exhibited expected responses to natural stimuli which may include nutrient supply, mixing processes, temperature, and other factors. The winter diatom bloom occurred in January when nutrients were plentiful. By February, it ceased until April and May. During these months with relatively high nutrient concentrations available and the onset of thermal stratification, the spring diatom bloom occured, flagellates reached peak concentrations, filamentous blue-green algae reached peak abundance, and filamentous green algae began their late spring - early summer bloom. In June when dissolved silica concentrations were low, diatom concentrations decreased and dilamentous green algae continued their summer bloom. In July, an upwelling displaced the existing water mass with one rich in nutrients and having a different phytoplankton community. During this month, diatoms reached peak concentrations, coccoid green algae and other algae began a summer bloom, and filamentous green algae concentrations were on the wain. In August and September, continued storms and upwelling maintained relatively high nutrient concentrations. During these months, pennate diatoms were relatively abundant, other algae and coccoid green algae continued to be found at high concentrations, and coccoid blue-green algae began their fall and early winter bloom. During October through December with the return to isothermal conditions, nutrient concentrations continued to be relatively high, coccoid green algae returned to low concentrations, coccoid blue-green algae continued their bloom, and pennate diatoms began their winter bloom. Of greatest importance was the high concentration of blue-green algae in January. This could be related to plant

operation. However, additional data will be needed to confirm or deny this observation.

Community structure changed between 1975 and 1976. The number of dominant or co-dominant occurrences of mesotrophic species not tolerant of nutrient enrichment decreased, of mesotrophic species tolerant of moderate nutrient enrichment increased, and of eutrophic species increased. In 1976, an increased number of forms was evident. All these changes appear to be characteristic of this region of Lake Michigan.

During 1976, an estimated maximum of 4.84×10^{18} plankton cells equivalent to roughly 2.76×10^{9} grams of phytoplankton were entrained by the Donald C. Cook Nuclear Plant. Of these, a maximum of 8.75% may be measureably impacted by the plant, with 5% being inhibited and 3.75% being enhanced. These estimates exclude those impacted by chlorination.

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